Appendix E2. b – Restoration Plans and TMDLs (Restoration Plans)

Attachment 2
Maryland Department of the Environment's (MDE) Review of Harford County's TMDL Restoration Plans for PCBs in Bush River and Sediment in Swan Creek

MDE's Integrated Water Planning Program completed a review of Harford County's TMDL Restoration Plans for PCBs in Bush River and sediment in Swan Creek. Clarifications, recommendations, and requests for more information are detailed below. MDE requests that comments are addressed with the next annual report submission.

<u>Bush River PCBs</u>

Clarifications:

- On Page 6, the last paragraph states that the "Chesapeake Bay model does not simulate the impacts of pollutants within the food chain…" However, MDE did not apply the Chesapeake Bay model to simulate the impacts of pollutants in developing the Bush River PCB TMDL. MDE developed a site-specific 1-D Numeric Water Quality Model for this TMDL. MDE suggests replacing "Chesapeake Bay Model" with "MDE's Bush River Water Quality Model" when applicable throughout the document.

- On Page 7, the first paragraph states that the "load from resuspension (3,328 g/year) is nearly 25 times greater than the contribution from the watershed (134.6 g/yr)." The load from resuspension is a gross load and does not consider exchanges between the water column and sediment through settling/deposition which significantly decreases the net load from the sediment. The gross load from settling is 9,661 g/year resulting in a net load of 6,333 g/year from the water column to the sediment. Therefore the sediment is not a source of PCBs to the water column under baseline conditions. Also the load associated with resuspension will decrease over time as contaminated sediment is buried with new cleaner sediment as a result of reductions to watershed loads and Bay mainstem water column concentrations. As there is a net load to the sediment, reductions are still required to the watershed in order to achieve water column and sediment TMDL endpoints.

- On Page 11, the first paragraph states that "in comparison to the resuspension loads for the Bush River (3,328 g/yr), a reduction by Harford County of 37.1 g/yr will be inconsequential in the reduction of PCBs in fish tissue…" As stated in the previous comment, the load from resuspension is a gross load and does not take into consideration the gross load from settling/deposition which significantly decreases the overall net load from the sediment. The gross load from settling is 9,661 g/year resulting in a net load of 6,333 g/year from the water column to the sediment. Therefore the sediment is not a source of PCBs to the water column under baseline conditions. The load from the watershed is not inconsequential as the water column and sediment TMDL endpoints will never be achieved without a reduction to the watershed load. A TMDL modeling scenario demonstrated that if sediments within the Bush River were clean, current loads of suspended sediments contaminated with PCBs from the watershed and Chesapeake Bay main stem would bury the clean sediment over time with contaminated materials resulting in sediment concentrations that exceed the TMDL endpoint.

Recommendations:

- The Source Assessment section of the implementation plan reallocates the baseline and TMDL watershed loads among regulated urban stormwater sources and non-regulated watershed runoff. Subsequently, the County disaggregates the regulated urban stormwater loads among the permitted entities in the watershed. The reallocation of loads is estimated by applying the percent urban land-cover within the individual subwatersheds to the total subwatershed loads, instead of at the aggregate Bush River watershed scale, as was done in the TMDL (County estimated regulated stormwater baseline load and WLA = 68.4 g/yr and 26.0 g/yr, respectively). While MDE guidance allows jurisdictions using their own modeling tools to calculate new baseline loads and associated WLAs based on equivalent levels of effort as specified in the TMDL, this scenario applies the same modeling tools, and therefore the newly proposed WLAs and LAs actually represent a proposed shift in TMDL allocations, which cannot be done in the implementation planning process. MDE would recommend removing this re-estimation of watershed WLAs and LAs from the implementation plan. The subsequent disaggregation of the regulated urban stormwater baseline loads and WLAs is still valid, but the calculations need to be revised to break out the regulated urban stormwater baseline loads and WLAs from the TMDL document, 49.7 g/yr and 18.89 g/yr, respectively.

- In addition to the sites and properties identified in the Restoration Plan section, MDE suggests identifying all industrial facilities with the potential to discharge PCBs in wastewater and stormwater discharges. This is an additional source sector that can be targeted in source trackdown monitoring. This list of industries can be identified via Standard Industrial Classification (SIC). Virginia has guidance on which SIC codes could be associated with PCB discharges. This guidance is attached to this set of comments.

- The implementation plan proposes to target TSS reductions in the watershed as PCBs have a strong affinity to sediment and reductions in TSS should lead to reductions in PCBs. As research is limited in regards to PCB removal effectiveness from stormwater best management practices (BMPs), the County could consider including BMP sampling within its monitoring plan. This information would be useful in estimating projected load reductions from BMPs planned for construction.

- The County indicates that it is planning to conduct storm event monitoring of TSS and PCBs at one location near the outlet of the Bynum Run watershed, since this is the most urbanized and has the largest flow contribution out of all the Bush River subwatersheds. In addition to the storm event monitoring, MDE would recommend collecting some baseflow samples, which would allow for complete tPCB load quantification from the watershed. MDE would also strongly recommend monitoring one of the other subwatersheds as well (if not all of them), at least as part of this initial monitoring effort in order to compare loads/concentrations. This will give a better indication of where additional source tracking should occur, if the County is planning on doing subsequent monitoring for source tracking purposes. MDE is willing to sit down and discuss with the County their proposed monitoring plan further, if so desired.

Requests for More Information:

- As referenced in the previous comment, the County indicates that it is planning to conduct storm event monitoring of TSS and PCBs. MDE has the following questions: Will this be done with automated sampling? Is there a time frame for sampling (when does the County plan on starting this effort)? What are the next steps following this initial monitoring? Does the County plan to conduct subsequent monitoring for source tracking purposes?

<u>Swan Creek Sediment</u>

Recommendations

- For most implementation plans, MDE recommends that the County perform its own modeling analysis, i.e., setting its own baseline load, recalculating its target load based on the allocated percent reduction in the TMDL, and subsequently developing planned implementation scenarios that demonstrate achievement of the required reduction. However, since the Swan Creek TSS TMDL requires a minimal 7 ton reduction in sediment from the Harford County MS4 permit area in the watershed, it seems reasonable that the County should not need to conduct its own modeling analysis in this case.

Requests for More Information

- The County indicates that it plans to achieve the entire 7 ton reduction in sediment by implementing a singular stream restoration project in the watershed. While this is an acceptable means of achieving the required reduction, MDE would still like to see an adaptive management component to the plan. This adaptive management component should discuss the use of monitoring data to confirm that the implemented stream restoration project, and ideally other projects, are making progress towards TMDL endpoints. The County should also keep in mind that there are multiple reaches with sediment/habitat stressors impacting biological communities (see Swan Creek Biological Stressor Identification report: http://www.mde.state.md.us/programs/Water/TMDL/Pages/bsid_studies.aspx) downstream of County owned stormwater conveyance systems in the watershed. While one stream restoration project may address the required sediment load reductions in the watershed, one restoration project will not make progress towards improving sediment and habitat related metrics on all impaired reaches in the watershed. This longer-term implementation process should be discussed in the adaptive management section of the implementation plan.

Bush River TMDL Restoration Plan for PCBs

Bush River Watershed
Total Maximum Daily Load (TMDL)
Restoration Plan for PCBs

December 2018 (Update)

August 2017

Prepared by:

Harford County Department of Public Works
Watershed Protection and Restoration Office

212 South Bond Street, 1st Floor
Bel Air, Maryland 21014

Barry Glassman
County Executive

Bush River Watershed

Total Maximum Daily Load (TMDL)

Restoration Plan for PCBs

December 2018 (Update)

August 2017

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Harford County, Maryland

Bush River Watershed Total Maximum Daily Load (TMDL) for PCBs

Introduction

The Bush River Watershed Total Maximum Daily Loads (TMDL) for Polychlorinated Biphenyls (PCBs) (April 2016) was established by Maryland Department of Environment (MDE) and approved by the U.S. Environmental Protection Agency (EPA) on August 2, 2016.

On December 30, 2014, MDE reissued the Phase I National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit to Harford County (County). The permit has several new requirements, including stringent stormwater management criteria, implementation of strategies to reduce litter and floatables, and development of restoration plans. Part IV.E.2.b of the NPDES MS4 permit requires the County to develop restoration plans to address stormwater wasteload allocations (SW-WLAs) for the waterbodies in the County that have EPA-approved TMDLs. Additionally, the County is required to develop restoration plans for subsequent TMDL SW-WLAs within one year of EPA approval.

Bush River was identified as impaired by PCBs in the 2014 Integrated Report developed by MDE for Sections 305(b) and 303(d) of the Clean Water Act (CWA). The impairment is based on PCBs in fish tissue (2002). The designated use for the Bush River is Use II, or estuarine and marine aquatic life and shellfish harvesting.

PCBs are man-made chemical compounds mainly manufactured as an insulator and coolant in transformers and capacitors. The manufacturing of PCBs was banned in 1977 based on its carcinogenic properties and its persistence to readily breakdown in the environment.

Four 8-digit basins drain into the Bush River including Atkisson Reservoir (02130703), Lower Winters Run (02130702), Bynum Run (02130704), and Bush River (02130701) (Figure 1). A TMDL for sediment for the Bynum Run Watershed was approved in September 2011. The County completed the *Bynum Run Watershed Total Maximum Daily Load Restoration Plan for Sediment* in March 2016.

Watershed Description

The Bush River Watershed is located entirely within Harford County and receives drainage from the Town of Bel Air and portions of the City of Aberdeen, both of which are Phase II MS4 jurisdictions. Additionally, a majority of the Bush River tidal mainstem receives direct drainage from Aberdeen Proving Ground (APG), a Phase II MS4 federal jurisdiction. APG which dates

Bush River Watershed TMDL Restoration Plan for PCBs

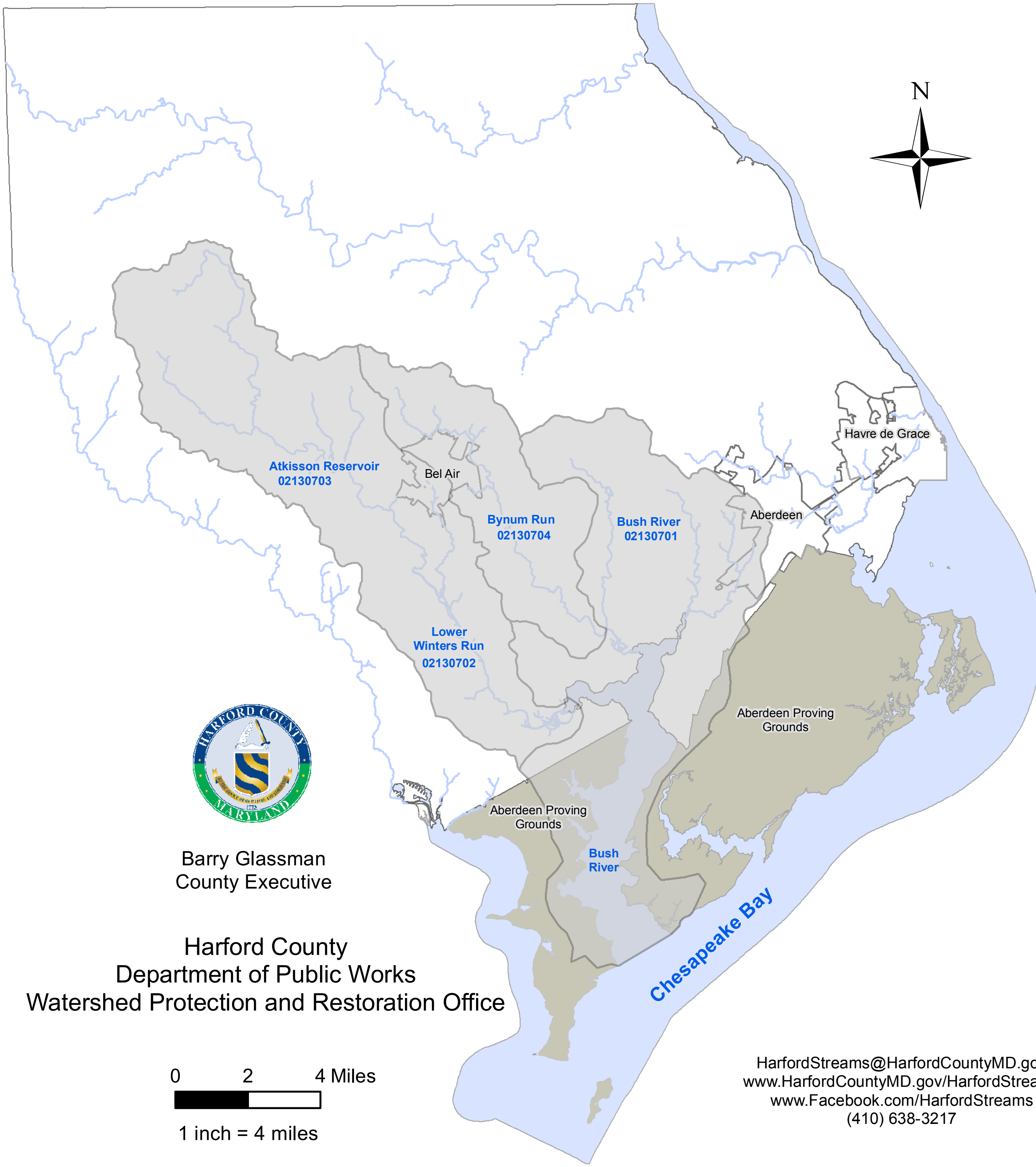

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Figure 1: Bush River Watershed 8-digit Basins

back to World War I, is the U.S. Army's oldest active proving grounds. http://armyalliance.org/about-apg/history-of-apg/). The portion of APG located on the western shore of the Bush River focused on chemical weapons research and development.

Bush River Watershed begins near the intersection of Norrisville Road and Jarrettsville Pike and extends southeast to the confluence of the Bush River and Chesapeake Bay. The watershed is roughly bounded on the west by Maryland Route 152, the northeast by Maryland Route 22, and the northwest by Jarrettsville Road / Old Federal Hill Road (Figure 2).

Bush River Watershed is the most urban watershed in the County. Most of the County's Priority Funding Area or development envelope is located within this watershed. The development envelope spans north to south from Forest Hill to Edgewood along MD Route 24 and east to west Aberdeen to Joppa along US Route 40.

The major tributaries to the Bush River are Otter Point Creek, Church Creek and Bynum Creek. Their tributaries include Winters Run, Bynum Run, James Run and Grays Run.

TMDL Development

Bush River was first identified as impaired in MDE's 2002 Integrated Report based on fish tissue sampling. The criteria for impairments is based on concentration in the water column and concentration in fish tissue. The human health criterion is based on consumption of fish and their interaction with the water column and food chain. "Drinking water consumption does not pose any risk for cancer development at environmentally relevant levels." (TMDL, 2016)

Table 1: PCB Criteria for Impairment

	Concentration
Water Column for Human Health	0.64 ng/L
Fish Tissue	39 ng/g

In 2013 and 2014, MDE conducted PCB monitoring for the water column for six tidal and four non-tidal locations (Figure 3). The data used to develop the TMDL was collected on three dates as shown in Table 2. The six tidal locations exceeded the PCB criteria for human health for 2 of 3 sample dates. All four non-tidal locations were significantly below the PCB criteria for human health for 2 of 3 sample dates.

Bush River Watershed TMDL Restoration Plan for PCBs

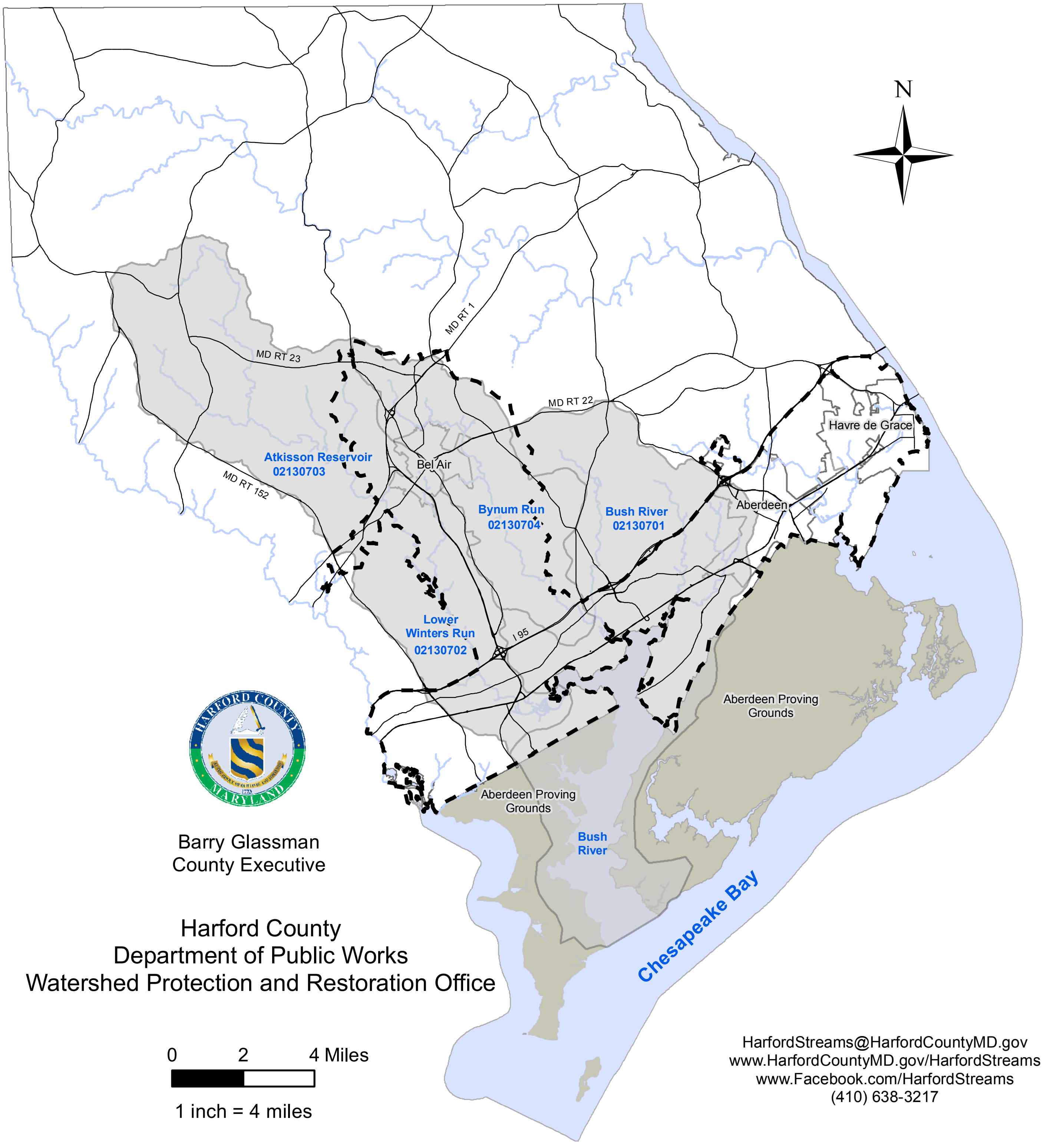


Figure 2: Bush River Watershed Location Map

Bush River Watershed TMDL Restoration Plan for PCBs

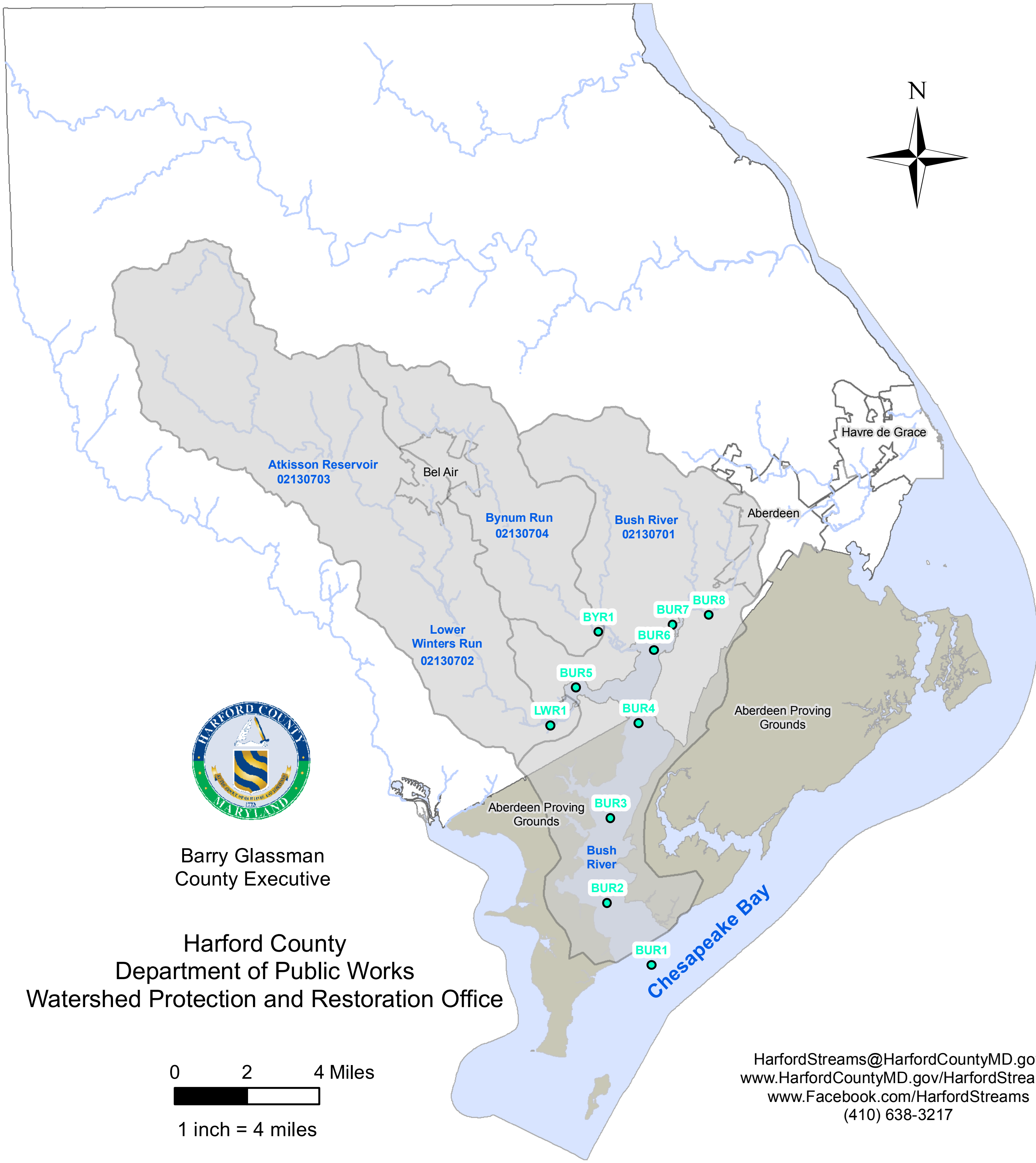


Figure 3: Bush River Watershed MDE Monitoring Locations

Table 2: MDE PCB Water Column Monitoring for Bush River TMDL (ng/L)

Station	Type	8/14/2013	10/30/2013	3/12/2014
BUR1	Tidal	0.90	0.35	1.20
BUR2	Tidal	1.34	0.51	4.64
BUR3	Tidal	2.02	0.37	4.00
BUR4	Tidal	2.15	0.87	5.19
BUR5	Tidal	0.80	0.33	1.56
BUR6	Tidal	1.46	1.16	8.43
BUR7	Non-tidal	0.01	0.03	1.15
BUR8	Non-tidal	0.00	0.03	1.72
BYR1	Non-tidal	0.02	0.01	7.20
LWR1	Non-tidal	0.02	0.03	0.44

In 2013 and 2014, MDE conducted PCB monitoring for sediment for five tidal locations (Figure 3). The data used to develop the TMDL was collected on two dates as shown in Table 3.

Table 3: MDE PCB Sediment Monitoring for Bush River TMDL (ng/g)

Station	Type	5/20/2013	10/3/2014
BUR2	Tidal	32.2	18.9
BUR3	Tidal	36.9	10.1
BUR4	Tidal	12.6	12.5
BUR5	Tidal	14.2	4.2
BUR6	Tidal	16.5	14.1

In 2014, MDE collected a total of thirty fish at BUR4 (Figure 3) for fish tissue sampling. The concentrations ranged from 54.22 ng/g to 658.96 ng/g which far exceed the impairment criterion of 39 ng/g. Therefore, demonstrating that a PCB impairment exists within the tidal mainstem of Bush River.

MDE used the Bush River Water Quality Model to calculate the PCB concentrations for the water column and sediment necessary to support fish tissue concentrations below the impairment criterion of 39 ng/g. Based on their analysis, the TMDL concentrations for the water column and sediment are listed in Table 4.

Table 4: TMDL Concentrations for PCBs

	Concentration
Water Column	0.12 ng/L
Sediment	1.14 ng/g

Source Assessment

While PCBs are no longer manufactured, there are many sources for existing PCBs including 1) transformers still allowed to be in use 2) buildings constructed or renovated before 1979 which used PCB-containing materials such as caulks, paints, fireproofing materials, and fluorescent light ballasts 3) improper disposal 4) tidal influence from Chesapeake Bay and 5) atmospheric deposition. PCBs also bind strongly with sediment and can be introduced to the water column through erosion or resuspension of sediments.

MDE's Bush River Water Quality Model through observed PCB concentrations has determined the net PCB load transported into the Bay from the Bush River is 1,049 g/year. Using concentration rates for urban areas from an atmospheric deposition study completed by the Chesapeake Bay Program, the PCB load from atmospheric deposition to the Bush River was calculated as 48.9 g/yr and the direct atmospheric deposition to the land surface of the Bush River Watershed as 538 g/year. Likewise, MDE has identified one known PCB contaminated site (MD 446 Union Road Dump) which contributes 2.37 g/yr.

Based on the average concentrations from the water column monitoring (Table 2) and stream flow from USGS stations within the watershed, loads for each of the non-tidal monitoring sites were calculated (Table 5). The total non-tidal load is 134.6 g/yr.

Table 5: MDE PCB Loads from Watershed Runoff

Watershed	Average Concentration (ng/L)	Load (g/yr)
Bush River	0.49	37.2
Bynum Run	2.41	85.3
Winters Run	0.16	12.1
		134.6

According to the TMDL document, "The transport of PCBs from bottom sediments to the water column through re-suspension and diffusion can be a major source of PCBs in estuarine systems". "The water quality model, applying observed tPCB concentrations in the water column and sediment, predicts a gross tPCB load of 3,328 g/yr from bottom sediment to the water column through re-suspension and diffusion in the Bush River. Although the transport of PCBs to the river from bottom sediment via re-suspension and diffusion is currently estimated to be the major source of PCBs, this load contribution is resultant from other point and nonpoint source inputs (both historic and current) and is not considered to be directly controllable. Therefore, this load will not be assigned a baseline load or allocation."

Stormwater Waste Load Allocation

The TMDL document calculates the stormwater waste load allocation (SW-WLA) for PCBs as the total contribution of urban land cover based on the 2006 USGS land cover data. The entire SW-WLA was collectively assigned to the regulated MS4 jurisdictions including Harford County, Town of Bel Air, City of Aberdeen, Aberdeen Proving Ground, and MD State Highway Administration. This analysis is based on MDE's expansive interpretation of the County's Permit Area in documents external to the County's current MS4 permit, which correctly defines the MS4 Permit Area in Part I.B. All rights noted above are reserved. This restoration plan develops strategies to reduce PCBs for the total urban loads within the physical boundaries of Harford County.

Using the 2006 USGS land cover data (downloaded from the TMDL Data Center), the County disaggregated the SW-WLA by calculating the urban land cover for each watershed (Table 6).

MDE did not calculate the urban load for each watershed. Instead, a total urban load was calculated as a percent of the total urban area or 36.9% of 134.6 g/yr, or 49.7 g/yr. The County calculated the baseline for each watershed based on the actual percent of urban land for each watershed. These values were then normalized using MDE's total urban load of 49.7 g/yr.

Table 6: PCB Loads by Watershed

	Bush River	Bynum Run	Winters Run	Total
Total (ac)	31,227	14,582	37,542	83,351
Urban (ac)	9,017	9,162	12,525	30,704
Urban (%)	28.9%	62.8%	33.4%	
Baseline (g/yr)	7.8	39.0	2.9	49.7
TMDL (g/yr)	3.0	14.8	1.1	18.9

Table 7: Town of Bel Air by Watershed

	Bush River	Bynum Run	Winters Run	Total
Total (ac)	0	1,094	855	1,948
Urban (ac)	0	992	798	1,789
Urban (%)	0	90.7%	93.3%	91.8%

Table 8: City of Aberdeen by Watershed

	Bush River	Bynum Run	Winters Run	Total
Total (ac)	1,135	0	0	1,135
Urban (ac)	893	0	0	893
Urban (%)	78.7%	0	0	78.7%

Table 9: Aberdeen Proving Ground by Watershed

	Bush River	Bynum Run	Winters Run	Total
Total (ac)	7,367	0	0	7,367
Urban (ac)	1,118	0	0	1,118
Urban (%)	15.1%	0	0	15.1%

Table 10: Harford County by Watershed

	Bush River	Bynum Run	Winters Run	Total
Total (ac)	22,726	13,488	36,687	72,901
Urban (ac)	7,006	8,170	11,728	26,904
Urban (%)	30.8%	60.6%	32.0%	36.9%

The urban load for each watershed was further disaggregated for each MS4 jurisdiction with exception for MD State Highway Administration. Tables 7 through 10 provide a breakdown of urban acres by watershed for each MS4 jurisdiction.

Using the urban acres for each MS4 jurisdiction, the percent contribution from each was calculated and summarized in Table 11.

Table 11: Urban Acres by Watershed for each MS4 Jurisdiction

Jurisdiction	Bush River	Bynum Run	Winters Run	Total
Bel Air	0	992 (11%)	798 (6%)	1,789 (6%)
Aberdeen	893 (10%)	0	0	893 (3%)
APG	1,118 (12%)	0	0	1,118 (4%)
County	7,006 (78%)	8,170 (89%)	11,728 (94%)	26,904 (87%)
	9,017 (100%)	9,162 (100%)	12,525 (100%)	30,704 (100%)

The County further disaggregated the baseline loads by watershed for each of the MS4 jurisdictions. The baseline loads by watershed for each jurisdiction was calculated as the product of the percent urban acres for each MS4 by watershed and the baseline watershed loads (Table 12).

Table 12: Baseline PCB Loads (g/yr) from Watershed Runoff by MS4 Jurisdiction

Jurisdiction	Bush River	Bynum Run	Winters Run	Total
Bel Air	0	4.2	0.2	4.4
Aberdeen	0.8	0	0	0.8
APG	1.0	0	0	1.0
County	6.0	34.8	2.7	43.5
	7.8	39.0	2.9	49.7

MDE through modeling calculated a 62% reduction in baseline loads from the watershed runoff was necessary in combination with a measured 6.5% annual decrease in sediments within Chesapeake Bay. This scenario will take approximately 81 years to achieve the designated use for Bush River.

Using a 62% reduction from baseline loads, TMDL loads for each jurisdiction by watershed was calculated (Table 13).

Table 13: TMDL PCB Loads (g/yr) from Watershed Runoff by MS4 Jurisdiction

Jurisdiction	Bush River	Bynum Run	Winters Run	Total
Bel Air	0	1.6	0.1	1.7
Aberdeen	0.3	0	0	0.3
APG	0.4	0	0	0.4
County	2.3	13.2	1.0	16.5
	3.0	14.8	1.1	18.9

Harford County's TMDL for PCB in the Bush River Watershed is 16.5 g/yr. In comparison to the resuspension loads for the Bush River, which MDE identifies as a major source of PCBs to the water column, a reduction by Harford County of 27.0 g/yr will be inconsequential in the reduction of PCBs in fish tissue and therefore the goal of supporting the Use II designation to support estuarine and marine aquatic life and shellfish harvesting. Likewise, the load contribution from the watersheds was based on averaging concentrations from three sampling dates, two of which were significantly below the TMDL concentration set for this watershed (Table 2).

Restoration Plan

Source Tracking

The County has identified several locations for further investigation as potential sources of PCBs.

A search of EPA's Superfund website (https://www.epa.gov/superfund/search-superfund-sites-where-you-live) lists three sites within Bush River Watershed (Table 14). Harford County will coordinate with MDE to determine if these sites are potential sources of PCBs.

Table 14: Superfund Sites within the Bush River Watershed

Site	Location
Aberdeen Proving Ground (Edgewood Area)	Edgewood, MD 21010
Aberdeen Proving Ground (Michaelsville Landfill)	Aberdeen, MD 21005
Bush Valley Landfill	Abingdon, MD 21009

According the Code of Federal Regulations any transformer that contains 500 ppm or greater PCB dielectric must be registered with EPA (https://www.epa.gov/pcbs/registering-transformers-containing-polychlorinated-biphenyls-pcbs. The registry includes three locations within Bush River Watershed (Table 15).

Table 15: PCB Registered Transformers within the Bush River Watershed

Site	Location
Aberdeen Proving Ground	Bldg E5863 Aberdeen, MD 21005
Aberdeen Proving Ground	Palmer & Access Road Aberdeen, MD 21005
Perryman Generating Station	900 Chelsea Road Aberdeen, MD 21001

All activities including the storage, transport, or disposal of PCBs must be reported to EPA (https://www.epa.gov/pcbs/notifications-polychlorinated-biphenyl-pcb-activities). The registry lists three locations within the Bush River Watershed (Table 16).

Table 16: PCB Activities within the Bush River Watershed

Site	Location	Activity
Aberdeen Proving Ground	Bldg E5850 Edgewood, MD 21010	Generator
City Light & Power EA Yard	Stokes and Hanlon Road Edgewood, MD 21040	Generator
City Light & Power EA Yard	3560 Crozier Loop Aberdeen, MD 21005	Generator

Under EPA's Toxics Release Inventory (TRI) Program (https://www.epa.gov/toxics-release-inventory-tri-program/tri-data-and-tools), PCBs are categorized as persistent bioaccumulative toxic (PBT) chemicals. The program tracks toxic releases through documentation required under the Emergency Planning and Community Right-to-Know Act (EPCRA). Eight facilities located within Bush River Watershed reported toxic releases within the preliminary inventory for 2016. None of the releases were for PCBs.

Virginia Department of Environmental Quality has well-established guidance for monitoring of point sources for PCBs (Guidance Memo No. 09-2001). This guidance provides a recommended list of Standard Industrial Classification (SIC) codes that are more likely to have impairments from PCBs (Table 17).

Table 17: SIC Codes for Industrial Facilities with Potential Impairments from PCBs

SIC Code	Code Operations	SIC Code	Code Operations
26 & 27	Paper and Allied Products	5093	Scrap Recycling
30	Rubber and Misc. Plastics	1221 & 1222	Bituminous Coal
33	Primary Metal Industries	3612	Transformers
34	Fabricated Metal Products	3731 & 3732	Ship / Boat Building / Repair
37	Transportation Equipment	4011	Railroad Transportation
49	Electrical, Gass and Sanitary Services	5015	Automobile Salvage Yards

Under EPA's National Pollutant Discharge Elimination System (NPDES) program, all industries that discharge process water or stormwater to surface or ground water must obtain an NPDES industrial permit. In Maryland, this program is administered through MDE. An inventory of these permits can be found at http://mes-mde.mde.state.md.us/WastewaterPermitPortal/

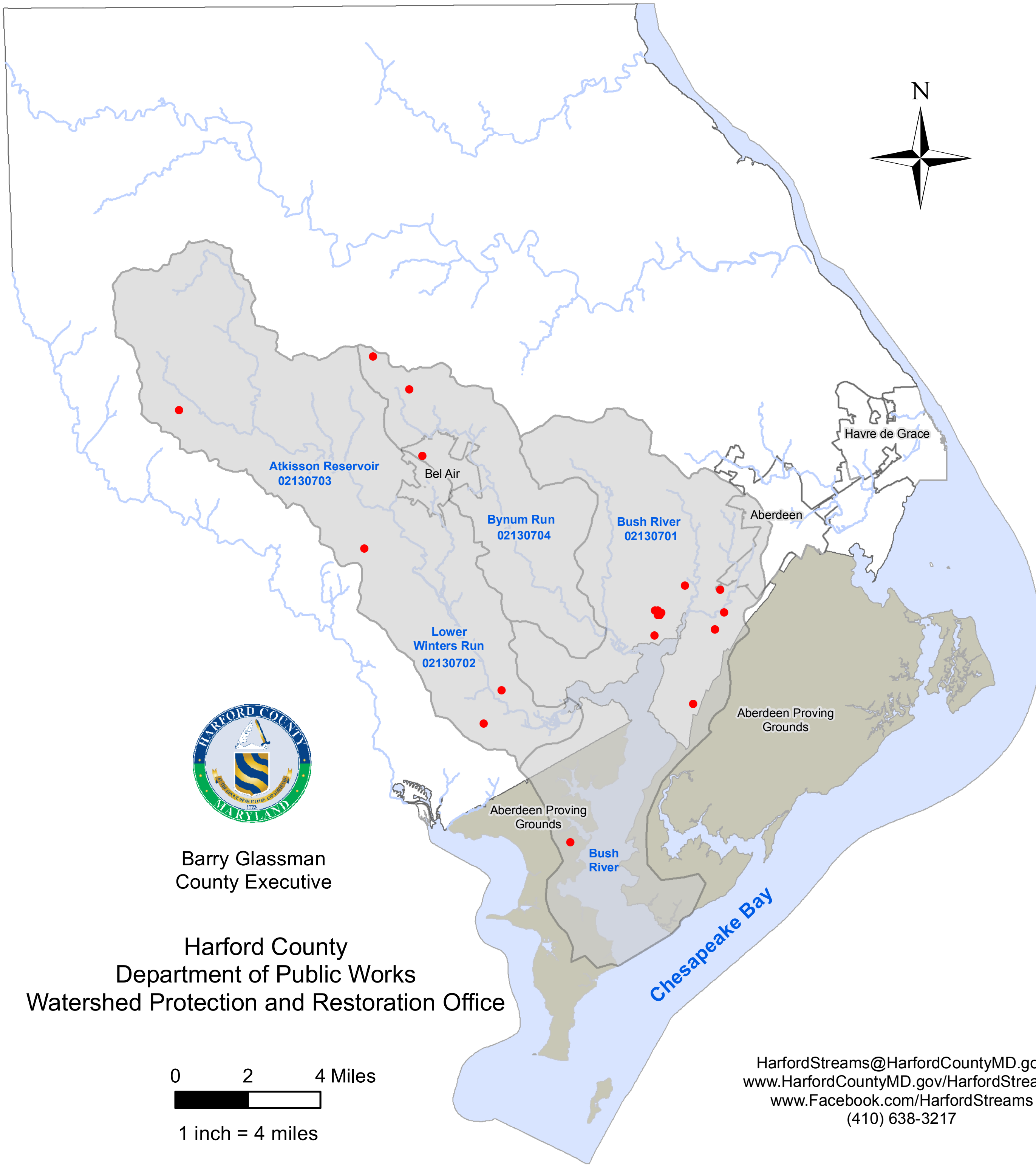
Within the Bush River watershed, this inventory includes twelve active permits and seven historic permits (Figure 4, Appendix A) with SIC codes from Table 17.

In addition to the locations listed above, several locations have been added for further investigation based on historic local knowledge (Table 18) and a list of properties constructed prior to 1980 with industrial landuse in the tax records (Table 19).

Table 18: Properties of Interest based on Historical Knowledge

Site	Location
Tollgate Landfill (Closed)	Tollgate Road Bel Air, MD 21014
Landfill (Closed)	Abingdon Road Abingdon, MD 21009
Bata (Redeveloped)	Pulaski Highway Belcamp, MD 21017
Landfill (Closed)	Philadelphia Road Abingdon, MD 21009

Bush River Watershed TMDL Restoration Plan for PCBs



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0 2 4 Miles

1 inch = 4 miles

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Figure 4: Bush River Watershed Industrial Permits with Priority SIC Codes for PCBs

Table 19: Properties of Interest based on Industrial Landuse

Tax ID	Location	Tax ID	Location
03194418	Bynum Road Forest Hill, MD 21050	03194396	Melrose Lane Forest Hill, MD 21050
03040186	Calvary Road Churchville, MD 21028	02001209	Old Philadelphia Road Aberdeen, MD 21001
01030078	Edgewood Road Edgewood, MD 21040	02013878	Old Philadelphia Road Aberdeen, MD 21001
01055038	Edgewood Road Bel Air, MD 21014	01073621	Philadelphia Road Aberdeen, MD 21001
03086925	Industry Lane Forest Hill, MD 21050	03050955	Snake Lane Churchville, MD 21028
03052044	Jarrettsville Road Forest Hill, MD 21050		

In addition to industrial use of PCBs, through the 1970s, PCBs were also used in building material including caulks, paints, fireproofing materials, and fluorescent light ballasts. The County will provide outreach to its own Facility Maintenance and Vertical Construction Engineering and Inspections Departments and Harford County Schools to ensure staff are familiar with potential existence of PCBs in older buildings considered for renovation or demolition. EPA's website provides a larger variety of educational materials (https://www.epa.gov/pcbs/polychlorinated-biphenyls-pcbs-building-materials)

Stormwater Management Facilities

According to the Toxics Work Group for the Chesapeake Bay Program, "Much of the PCB load moving through urban watersheds is potentially treatable by stormwater retrofits." They continue by noting that "Remarkably little monitoring has been conducted to assess whether urban stormwater BMPs can remove PCBs", and reference research conducted by Yee and Mckee (2010) which concluded that PCBs behaved very similar to sediments. Therefore, along with the implementation of the Bynum Run Sediment TMDL Restoration Plan, all dredge materials from stormwater management facilities retrofitted for restoration will be tested for PCBs using EPA Method 1668.

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Monitoring Plan

The stormwater wasteload allocation developed by MDE was based on watershed runoff loads for a limited number of sample dates and results with considerable variability. Therefore, the County proposes to provide additional monitoring to better quantify the extent of the PCB loads prior to investing large quantities of funding for capital improvement projects.

The County is actively pursing a partnership with University of Maryland Baltimore County through MDE to develop and implement a monitoring plan using passive samplers. While the specifics of the monitoring plan will be completed over the next several months, the County anticipates initially sampling at each non-tidal location sampled by MDE and two tidal locations (Figure ?). The laboratory analysis will follow EPA Method 1668 for inclusion of the congeners analyzed by MDE. Initial sampling is anticipated to take place in spring and fall 2019. Sample results will be used to determine the need for source tracking and / or additional monitoring. The non-tidal sample locations are all located at the downstream end of very large watersheds, making source tracking from the initial monitoring difficult. Additional locations will be sampled upstream of locations with results significantly over the water column criteria of 0.64 ng/L (ie. over 2.0 ng/L). Additional sampling will be used until the location of a potential source of PCBs can be isolated. Once isolated, current and historic use of the properties will be investigated. The County will work with MDE Compliance as necessary to mitigate the PCB source.

Since the PCB TMDL for Bush River is based on the presence of PCBs in fish tissue, the County will coordinate with MDE to determine if a schedule for future fish sampling in Bush River has been established.

Conclusion

The County will report monitoring plan results from the passive samplers and status of source tracking and sample results from materials dredged from stormwater retrofits in the annual MS4 report. Any necessary modifications to the plan will also be documented. In 2023, the County anticipates updating this plan and incorporating annual evaluations and any new developments or recommendations from the research community for PCB abatement.

The Toxics Work Group for the Chesapeake Bay Program has developed the “Toxic Contaminants Policy and Prevention Outcome, Management Strategy” that outlines specific approaches for regulations, education and awareness, voluntary programs, and science. By implementing these management approaches, federal, state, and local agencies can move forward in reducing toxic impacts within our waters in the most cost effective and beneficial manner.

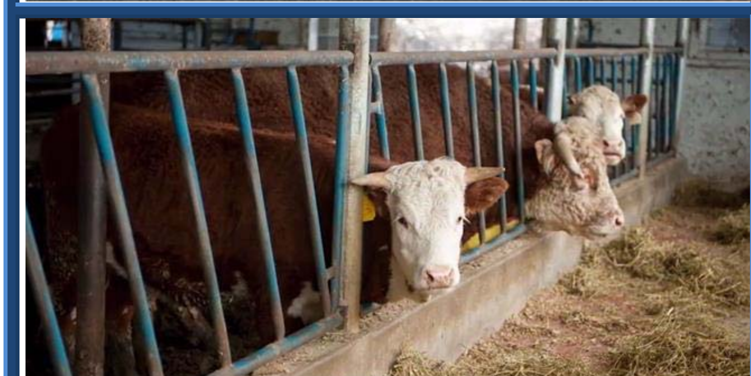
Over the past year, Harford County has attended two workshops sponsored by the U.S. Geological Survey focused on toxics and PCBs. The County appreciates the opportunity to interact with practitioners and researchers in this field and welcomes continued discussions into the future.

Appendix A: Industrial NPDES Permitted Sites with Priority SIC Codes in Bush River Watershed

Facility_N	Address	City_1	Zip_Code	State_Num_	Status_1	Status_Dat
Alcore, Inc	1502 Quarry Dr	Edgewood	21040	02SW1247	History	9/14/2014
Alcore, Inc	1502 Quarry Dr	Edgewood	21040	12NE1247	Issued	9/15/2014
American Color Graphics	1211 Belmar Dr	Belcamp	21017	02SW0164	History	6/15/2015
Bizerba Label Solutions	105 Industry Lane	Forest Hill	21050	02SW1827	History	3/8/2009
Bottcher America Corporation	4600 Mercedes Dr	Belcamp	21017	02SW0487	History	5/11/2015
Bottcher America Corporation	4600 Mercedes Dr	Belcamp	21017	12SR0487o	Issued	6/12/2015
Constellation Power - Perryman Generating Station	900 Chelsea Rd	Aberdeen	21001	06HT5131	History	8/15/2011
Constellation Power - Perryman Generating Station	900 Chelsea Rd	Aberdeen	21001	11HT5131	History	7/28/2014
Constellation Power - Perryman Generating Station	900 Chelsea Rd	Aberdeen	21001	11HT5131A	Issued	7/29/2014
Crown Speciality Packaging	4606 Richlynn Dr	Belcamp	21017	08NE1597	History	1/9/2013
Crown Speciality Packaging	4606 Richlynn Dr	Belcamp	21017	12NE1597o	History	9/8/2014
Crown Speciality Packaging	4606 Richlynn Dr	Belcamp	21017	12SW1597	Issued	9/9/2014
Greenridge Utilites, inc	506-A Fountain Green Rd	Bel Air	21015	06HT9526	History	3/31/2006
Greenridge Utilites, inc	506-A Fountain Green Rd	Bel Air	21015	11HT9526	Issued	8/2/2012
Independent Can Company	1300 Brass Mill Rd	Belcamp	21017	10DP2681	Issued	1/1/2012

Independent Can Company	1300 Brass Mill Rd	Belcamp	21017	17DP2681	Received	3/29/2017
Lifoam Industries, LLC	121 Bata Blvd	Belcamp	21017	02SW2347	History	9/7/2014
Lifoam Industries, LLC	121 Bata Blvd	Belcamp	21017	12SW2347	Issued	9/8/2014
LKQ Pick Your Part (1209)	1706 Pulaski Hwy	Edgewood	21040	02SW0539	History	12/23/2013
LKQ Pick Your Part (1209)	1706 Pulaski Hwy	Edgewood	21040	02SW2259	History	8/3/2011
LKQ Pick Your Part (1209)	1706 Pulaski Hwy	Edgewood	21040	12SR2259	Issued	3/30/2015
Mark/trece, Inc.	112 Connolly Rd	Fallston	21047	04NE3036	History	2/26/2015
Mark/trece, Inc.	112 Connolly Rd	Fallston	21047	12NE3036	Issued	2/27/2015
Maryland Used Auto Parts	1001-1009 Pulaski Hwy	Joppa	21085	12SR3120	Issued	6/8/2017
Master-Halco, Inc.	1720 Trimble Rd	Edgewood	21040	02SW1419	History	3/9/2006
Norman's New & Used Auto Parts, Inc	1301 S Philadelphia Blvd	Aberdeen	21001	12SW2279	History	12/8/2014
PS Publications Services	29 Ellendale St, Ste C	Bel Air	21014	02SW1354	History	4/12/2010
Sod Run WWTP	1212 Chelsea Rd	Perryman	21005	02SW1727	History	10/1/2014
Sod Run WWTP	1212 Chelsea Rd	Perryman	21005	12SW1727	Issued	10/2/2014
Sod Run WWTP	1212 Chelsea Rd	Perryman	21005	15DP1580	Issued	3/1/2016
WAVE - Worthington Armstrong Venture	1415 Perryman Rd	Aberdeen	21001	12NE1391	Issued	9/19/2014

WAVE - Worthington Armstrong Venture	1415 Perryman Rd	Aberdeen	21001	12NE1391o	History	9/18/2014



Swan Creek Watershed Total Maximum Daily Load Restoration Plan for Sediment

December 2018 (Update)
September 2017

Prepared for:
Harford County
Department of Public Works
212 South Bond Street
Bel Air, MD 21014

Prepared by:
AECOM
12420 Milestone Center Drive,
Suite 150
Germantown, MD 20876

SWAN CREEK WATERSHED TOTAL MAXIMUM DAILY LOAD RESTORATION PLAN FOR SEDIMENT

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12-SW	Industrial General Permit for Stormwater Discharges
BMP	best management practice
BSID	Biological Stress Identification
CBP	Chesapeake Bay Program
CIP	Capital Improvement Program
COMAR	Code of Maryland Regulations
County	Harford County
CWA	Clean Water Act
DPW	Harford County Department of Public Works
EOS	Edge of stream
EPA	U.S. Environmental Protection Agency
ESC	Erosion and Sediment Control
ESD	environmental site design
GIS	geographic information system
HOA	Homeowners Association
HSG	Hydrologic Soil Group
lb	pound
MDE	Maryland Department of the Environment
MD SHA	Maryland State Highway Administration
MGD	millions of gallons per day
mg/l	milligrams per liter
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
SPSC	step pool storm conveyance system
TMDL	Total Maximum Daily Load
TSS	total suspended solids

SECTION ONE: INTRODUCTION

The Swan Creek Watershed Total Maximum Daily Load (TMDL) Restoration Plan for sediment, developed by Harford County (County) Department of Public Works (DPW), will serve as a guideline for the County to reduce sediment in the Swan Creek Watershed. This TMDL was established by Maryland Department of Environment (MDE) and approved by U.S. Environmental Protection Agency (EPA) in September 2016.

On December 30, 2014 MDE reissued the Phase I National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit to the County. The permit has several new requirements, including stringent stormwater management criteria, implementation of strategies to reduce litter and floatables and development of restoration plans. Part IV.E.2.b of the NPDES MS4 permit requires the County to develop restoration plans to address stormwater wasteload allocations (SW-WLAs) for all the waterbodies in the County which have EPA approved TMDLs. Attachment B of the County's NPDES MS4 permit lists eight waterbodies which have local and Chesapeake Bay TMDLs for various impairments. Since the County's MS4 permit was issued TMDLs were approved for the Bush River for PCBs and Swan Creek for Sediment. Table 1-1 lists the watersheds, type of TMDL, and the impairment.

Table 1-1: EPA Approved TMDLs in Harford County

Type of TMDL	Watershed	Impairment
Local	Bush River	PCBs
	Bynum Run	Sediment
	Swan Creek	Nutrients and Sediment
	Loch Raven Reservoir (Non-Tidal)	Bacteria
	Loch Raven Reservoir	Mercury
	Loch Raven Reservoir	Nutrients and Sediment
Chesapeake Bay	Bush River Oligohaline	Nutrients and Sediment
	Gunpowder River Oligohaline	Nutrients and Sediment
	Chesapeake Bay Mainstem 1 Tidal Fresh	Nutrients and Sediment
	Chesapeake Bay Mainstem 2 Oligohaline	Nutrients and Sediment

This Plan only addresses the Swan Creek TMDL for sediment. The Swan Creek Watershed (MDE 8-digit: 02130706), a subwatershed of the Northern Chesapeake Bay Tidal Fresh Watershed (MDE: CB1TF), lies entirely in Harford County and includes, Aberdeen Proving Grounds (APG), a federal Phase II NPDES MS4 community and the cities of Aberdeen and Havre de Grace, municipal Phase II NPDES MS4 communities. The watershed also includes State-owned properties and State highways. Figure 1-1 shows the location of the Swan Creek Watershed in the County.

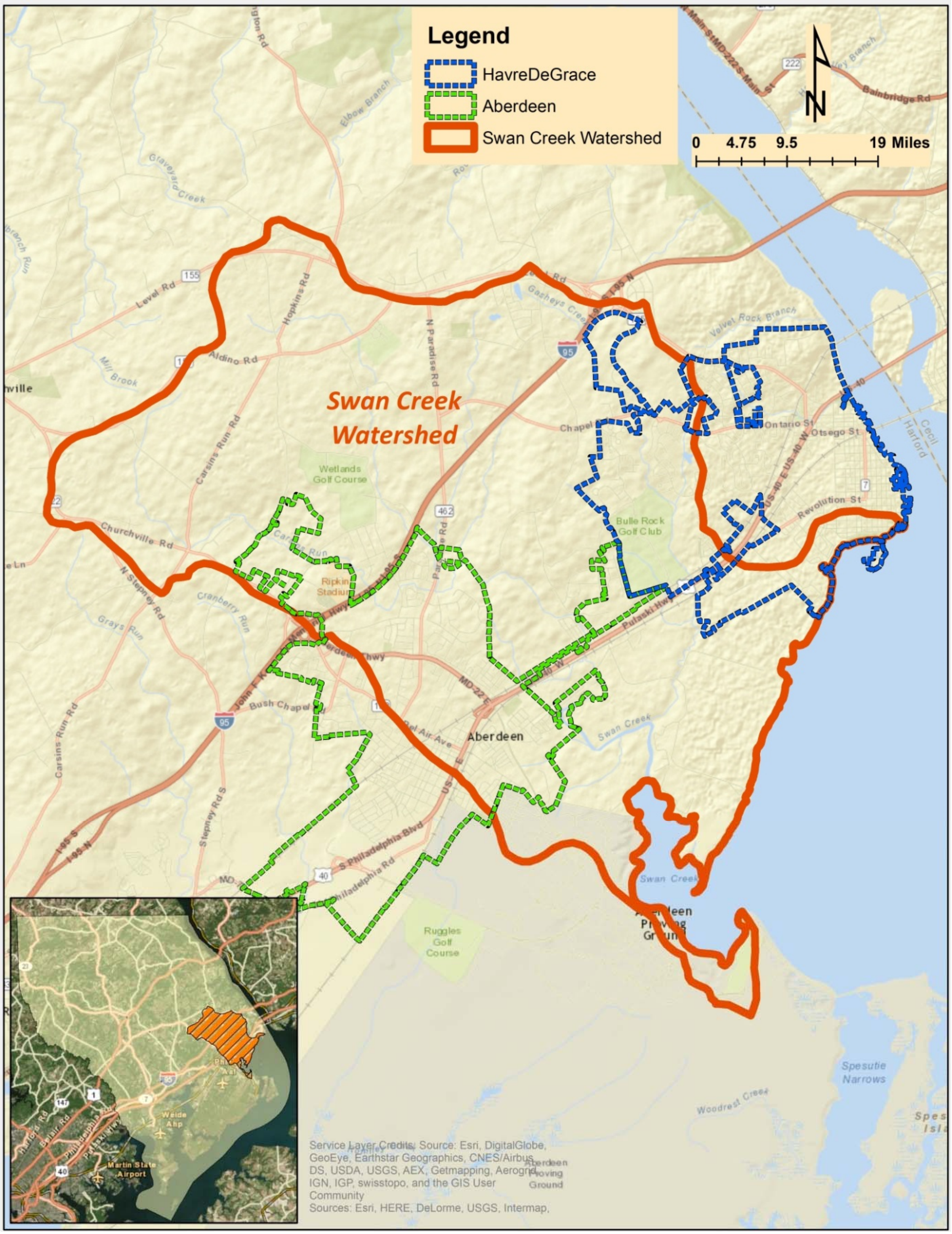


Figure 1-1: Watershed Location Map

1.1 WATERSHED DESCRIPTION

Swan Creek Watershed is in the southeastern portion of Harford County. The watershed's approximate borders include Route 155 to the north, Canvasback Drive to the northeast, Chesapeake Bay to the southeast, and Bel Air Avenue to the southwest. Approximately 60 percent of the City of Aberdeen and 45 percent of the City of Havre de Grace is in the Swan Creek Watershed.

Swan Creek headwaters are located just east of the Harford County Airport, and extends southeast to the confluence with Gashey's Creek south of Pulaski Highway. These streams converge and drain to Chesapeake Bay at Swan Creek Point. Gashey's Creek is a critical habitat for the federally endangered Maryland darter.

1.2 MDE DESIGNATED USE OF SURFACE WATERS

MDE has classified all the water bodies in the State including streams, impoundments and tidal waters based on their designated use [Code of Maryland Regulations (COMAR) Section 26.08.02.08].

The majority of Swan Creek and its tributaries are classified as Designated Use Class I waters, which support water contact recreation, propagate growth of fish (not trout) and other aquatic life, fishing, and agricultural and industrial water supply. The downstream segment of Swan Creek between U.S. Route 40 (Pulaski Highway) and the Bay is Designated Use Class II, which in addition to the Class I activities, supports prorogation of shellfish, migratory fish spawning, fish and shellfish use, and seasonal deep-channel refuge use. There are no impoundments in the watershed. The receiving waterbody, Northern Chesapeake Bay Tidal Fresh, is Class II-P and supports all activities above as well as being a source of public potable water (Figure 1-2).

1.3 MARYLAND HIGH QUALITY WATERS (TIER II)

According to COMAR 26.08.02.04-1, high quality waters (Tier II) are where the water quality is better than the minimum requirements specified by the water quality standards. MDE restricts any watershed restoration or other activities that would affect Tier II waters, including new discharges or major modifications to existing discharges to these high quality waterbodies. MDE data indicate that there are no Tier II waters in the Swan Creek Watershed; therefore, restoration project locations are not restricted within the watershed.

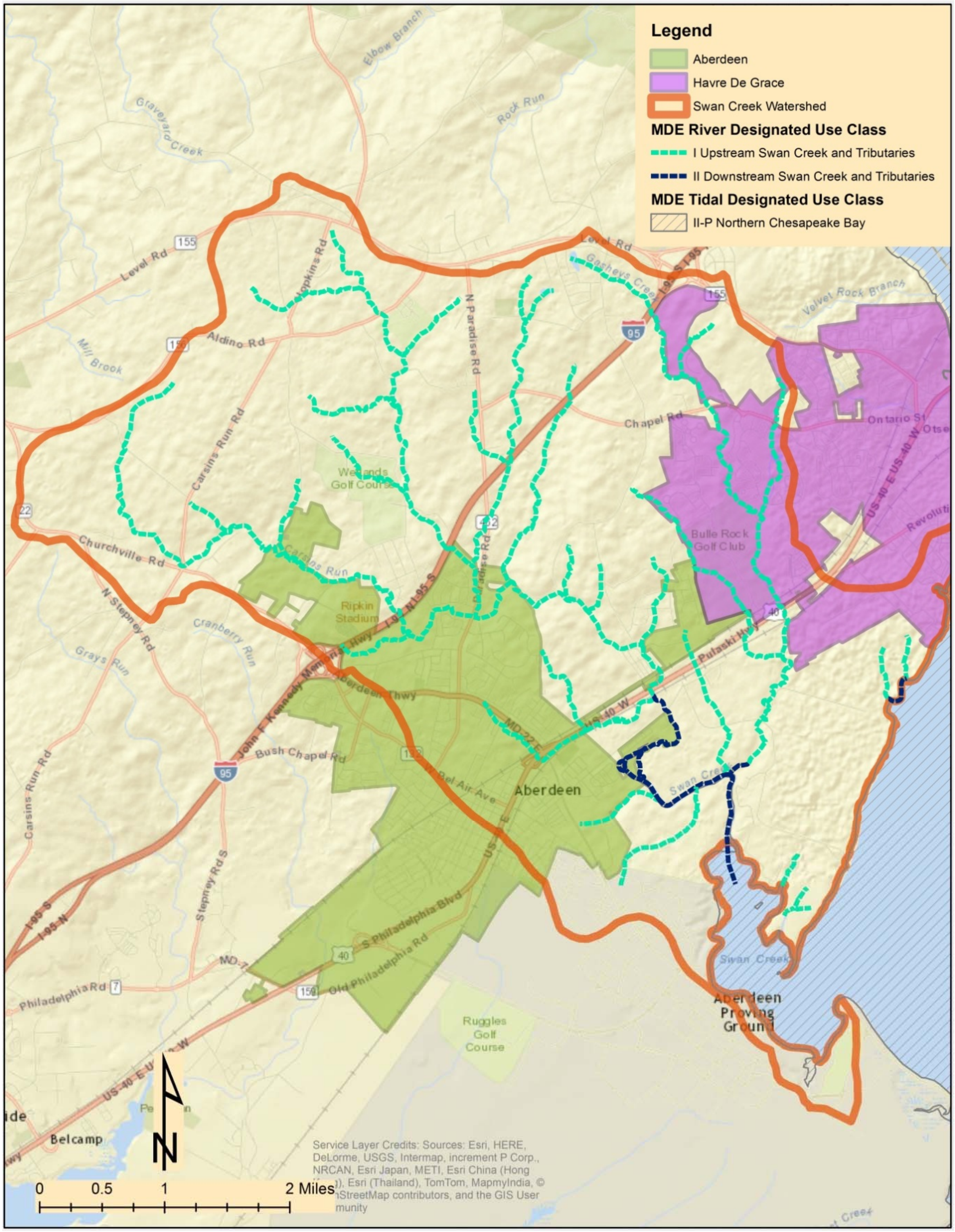


Figure 1-2: MDE Designated Use for Surface Waters in Swan Creek Watershed

1.4 DEVELOPMENT OF TMDL FOR SWAN CREEK

A TMDL is a calculation of the maximum amount of a pollutant a water body can receive and still meet the State water quality standards and designated uses. TMDLs are generally developed using pollutant load models or mathematical models which are calibrated using monitoring data.

Swan Creek was identified as impaired by sediment in the 2014 Integrated Report developed by MDE for Sections 305(b) and 303(d) of the Clean Water Act (CWA). To estimate the impact of sediment loads, MDE performed a Biological Stressor Identification (BSID) Analysis. Based on the results of the analysis, MDE concluded that biological communities within the non-tidal portions of the watershed were impacted by low dissolved oxygen saturation and high pH from altered flow/sediment and instream habitat stressors.

The Chesapeake Bay Program P5.3.2 watershed model was used to estimate the sediment loads within Swan Creek and specifically used the edge of stream (EOS) sediment loads. These baselines were used to assign reduction goals for the Swan Creek Watershed. The baseline loads were calculated using landuse from 2006.

In September 2016, EPA approved the Swan Creek TMDL for sediment. The baseline load is 770 tons per year with the TMDL goal of 729 tons per year, or an overall 5% reduction in loading within the entire watershed.

1.5 SOURCES OF IMPAIRMENT

The TMDL document developed by MDE quantified sediment loads from point and non-point sources in the watershed. The only reduction MDE has assigned is for urban stormwater despite the fact that the watershed is comprised of 33 percent row crops (TMDL document, Table 5) verses 53 percent regulated urban.

1.5.1 Non-Point Sources

Non-point sources of sediment loads include crop, pasture, and forest. MDE's TMDL document identified that approximately 35 percent of the total sediment loads in the watershed are from agricultural areas, and that forest areas contribute approximately 12 percent of the total sediment loads. The total sediment load from non-point sources is 361 tons per year. MDE assigned no load reductions for non-point sources.

1.5.2 Point Sources

Several permitted point sources in the watershed were identified (Table 1-2). The total load from point sources is 407 tons per year. The Swan Harbor Dell Mobile Home Park, also identified as a point source, contributes 2 tons/year but was not assigned a load reduction. The Town of Bel Air identified in MDE's TMDL document, is not in the Swan Creek Watershed. It is in the Bynum Run and Winters Run watersheds and is therefore not included in Table 1-2.

Table 1-2: Stormwater Point Sources in Swan Creek Watershed

Facility Name	Permit Type	Contribution of Point Source Loads (%)
Harford County	NPDES MS4 Phase I	15
City of Aberdeen	NPDES MS4 Phase II	43
City of Havre de Grace	NPDES MS4 Phase II	
State Highway Administration	NPDES MS4 Phase I	7
Comer Construction, Inc.	Other NPDES	33
Harford Systems, Inc.	Other NPDES	
Plastipak Packaging, Inc.	Other NPDES	
Smuckers Quality Beverages, Inc.	Other NPDES	
MDE General Permit to Construct	Other NPDES	
		100

1.6 TMDL ALLOCATION FOR STORMWATER WASTE LOAD ALLOCATIONS

TMDL targets were only assigned to the urban sources in the watershed. No targets were assigned to the non-point sources.

The Swan Creek TMDL for sediment requires an overall 5 percent reduction from the baseline. This load reduction was distributed among the point sources in the watershed. Table 1-3 lists the TMDL load reduction targets for the point sources. Harford County's load reduction is 7 tons/year.

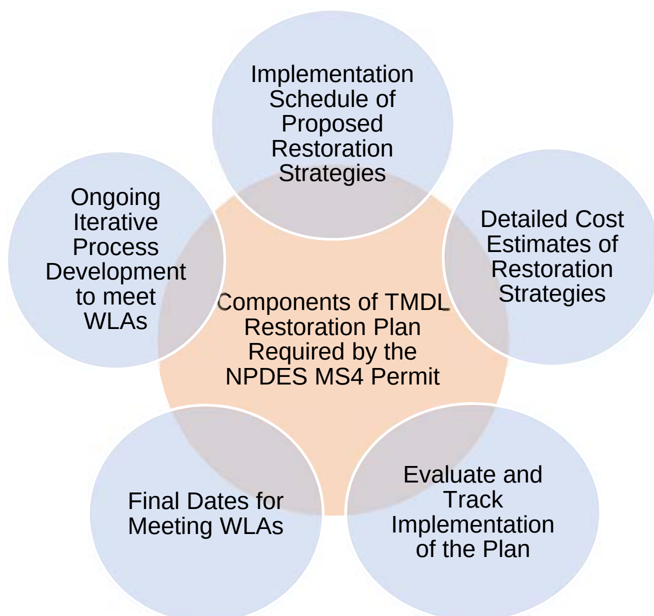
Table 1-3: Load Reductions for Stormwater Point Sources in Swan Creek Watershed

Facility Name	Permit Type	Load Reductions (tons/year)	Required Reduction (%)
Harford County	NPDES MS4 Phase I	7	13
Town of Bel Air	NPDES MS4 Phase II	23	13
City of Aberdeen	NPDES MS4 Phase II		
City of Havre de Grace	NPDES MS4 Phase II		
State Highway Administration	NPDES MS4 Phase I	4	13
Other NPDES Regulated Stormwater	Other NPDES	6	4

1.7 REQUIREMENTS OF A TMDL RESTORATION PLAN

A TMDL Restoration Plan is a roadmap that identifies various water quality improvement strategies that a local jurisdiction can implement to reduce loadings of a particular pollutant in a specific impaired watershed. The graphic below summaries MDE's requirements for restoration plans as outlined in the County MS4 permit. The County reserves the right to make arguments regarding the legality of the plan requirements notwithstanding their presentation in this plan. The Swan Creek TMDL focuses only on reducing sediment loads from the urban stormwater portion of the watershed.

The main objective of a TMDL restoration plan is to recommend a wide array of structural, non-structural and/or programmatic management strategies that could be implemented at the watershed-scale level (rather than site specific).



SECTION TWO: RESTORATION STRATEGY

The County's contribution towards the baseline load for sediment accounts for only 8% of the overall load. Likewise, the wasteload reduction of 7 tons/year will account for only 18% of the required reduction (Table 2-1).

Table 2-1: Swan Creek Sediment Baseline Loads and Allocations by Source

Restoration Practice	Baseline Load (tons/year)	% Baseline	Reduction (tons/year)	% Reduction
Forest	90	12%	0	0%
Agriculture	270	35%	0	0%
Harford County Phase I MS4	63	8%	7	18%
Municipal Phase II MS4	177	23%	23	58%
SHA Phase I MS4	30	4%	4	10%
Other Regulated NPDES	138	18%	6	15%
Total	768		40	

The County has chosen to develop a restoration strategy focused on stream restoration. Stream restoration stabilizes the stream banks and improves riparian buffers, thus improving habitat, increasing dissolved oxygen and decreasing sedimentation. Programmatic strategies developed for the County's Chesapeake Bay TMDL Restoration Plan are proposed county-wide and will include the Swan Creek Watershed.

2.1 PROJECT SELECTION

A desktop analysis of the watershed was completed to identify large parcels with minimal riparian buffer. Those areas are likely to have unstable stream banks and therefore poor biological communities and habitat; minimal disturbance to existing riparian buffers during construction; and less staff time to obtain easements for construction.

Twenty-four areas were identified through this desktop analysis and assigned a priority of high, medium and low. Priorities were based on proximity to MBSS sites with failing parameters, length of stream, amount of existing riparian buffer, and past interactions with potential property owners. Nine areas were ranked as high priorities (Figure 2-1). Six of the nine areas are located on agricultural properties. The County has been working with the Harford Soil Conservation District to coordinate contact with those property owners.

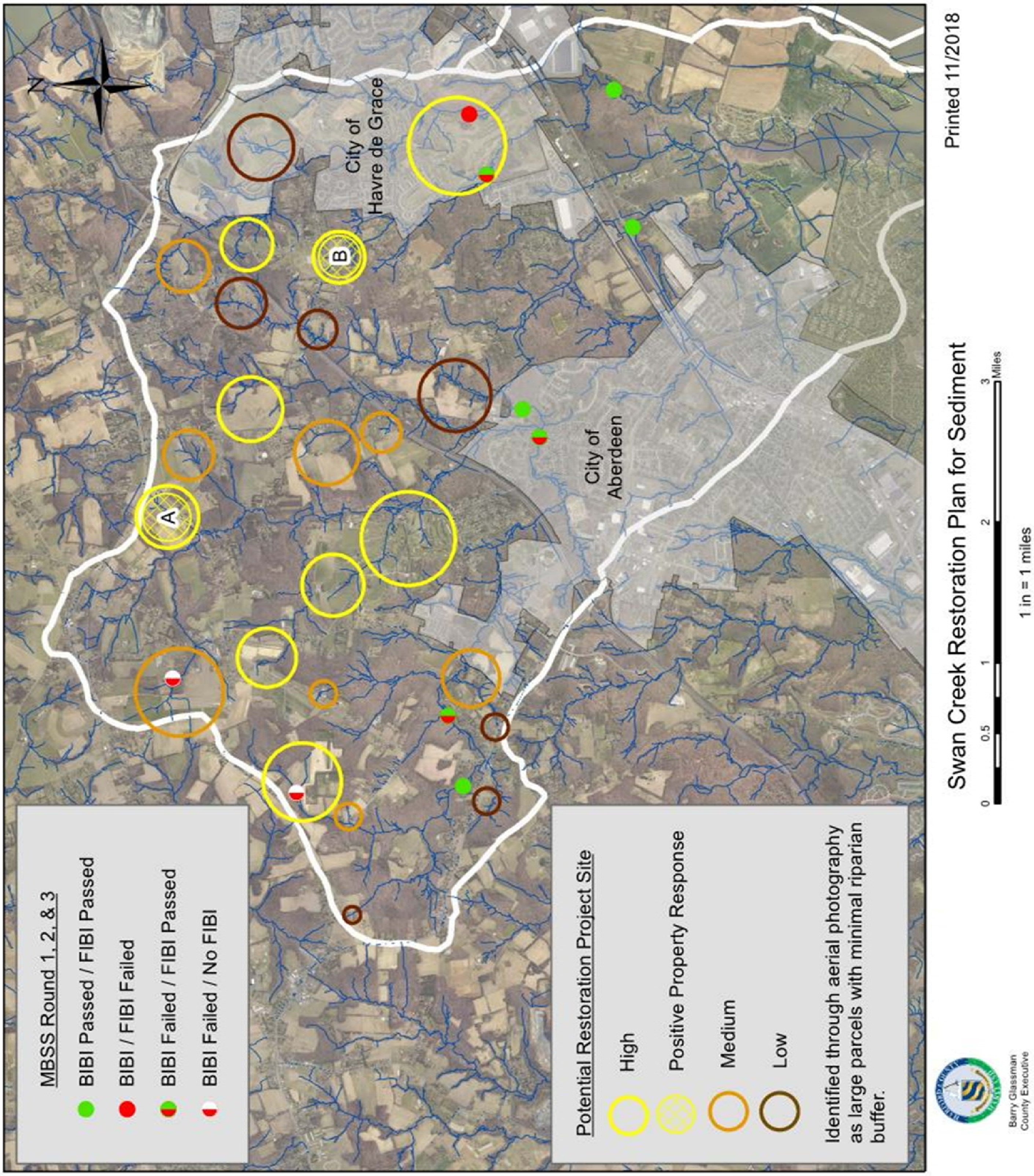


Figure 2-1: Prioritized Areas for Potential Stream Restoration Projects in Swan Creek

2.2 IMPLEMENTATION SCHEDULE

Property owners for four of the nine areas have been contacted. Property owners for two of the four areas denied access for evaluation. These owners have not been identified on Figure 2.1 to protect the property owner's privacy. The property owners for the remaining areas have expressed interest in participating in a restoration on their properties. These areas have been labeled A and B in Figure 2-1. Meetings with these property owners, coordinated through Harford Soil Conservation, will take place in January 2019.

The County anticipates completing evaluations for these properties in late winter / early spring 2019. Since neither of these sites are within proximity to existing failing MBSS sites, the evaluations will include biological and habitat assessments using MBSS protocols. Only sites failing MBSS protocols will be pursued. If one or more of the evaluations identify a project, the County will pursue the design(s) and construction under an existing design – build on-call contract. Design(s) would begin summer 2019 with construction summer 2020.

Should these evaluations produce no viable projects, the property owners for the remaining five high priority areas will be contacted in summer 2019, followed by medium priority areas in fall 2019 as needed.

2.3 IMPLEMENTATION COSTS

Estimated costs for the design and construction for a stream restoration vary between $200 and $500 per linear foot. While, a total stream length of approximately 500 linear feet of restoration would produce the required sediment load reduction of 7 tons per year, the County anticipates pursing project(s) with a minimum stream length of 1,000 linear feet. Table 2.2 lists the projected costs for the two potential areas identified as A and B in Figure 2.1. The cost for restoration of 3,000 linear feet would cost approximately $1,500,000. The County will incorporate these project(s) into its existing capital improvement program for watershed restoration to address the County's MS4 permit.

Table 2-2: Stream Restoration Strategy for Swan Creek Watershed

Project	Stream Length (feet)	Design	Construction	Total
A	2,000	$200,000	$800,000	$1,000,000
B	1,000	$100,000	$400,000	$500,000
Total	3,000	$300,000	$1,200,000	$1,500,000

* Total = $500 per foot, Design = 20% of total, Construction = 75% of total

2.4 TRACKING AND EVALUATION

The design for all stream restoration project(s) completed within the Swan Creek watershed will incorporate the criteria from the Chesapeake Bay Program's Expert Panel on Stream Restoration (September 2014). This will include the necessary physical monitoring to quantify pre-design load reductions, post-construction physical monitoring to ensure long-term stability, and pre and post-construction habitat and biological monitoring using MBSS protocols. Additional pre and post-construction habitat and biological monitoring sites will also be established upstream and downstream of the restored stream as applicable.

While a watershed-wide biological/habitat monitoring program would provide a measurement of whether the TMDL reduction has been met, establishing this program within a watershed outside of the urbanized areas within the County may not be cost effective. Likewise, the County's contribution towards the overall baseline and the allocated reduction are both very minor (Table 2.1). Commitment from the other sources to complete their share of the load reduction (72%) should be completed before this type of monitoring program is pursued.

Final targets to access reductions in sediment and improvements to water quality will include biologic and fish indices of 3.0 and increases in dissolved oxygen and decreases in pH. These targets will be reviewed on a five-year cycle for the restored stream(s) only until additional sources have completed their required restoration and a watershed-wide monitoring program can be established.

The County will report implementation status, load reductions, and monitoring results in the annual MS4 report. Any necessary modifications to the plan will also be documented. In 2023, the County anticipates updating this plan and incorporating annual evaluations.

SECTION THREE: CONCLUSION

The County anticipates addressing its stormwater wasteload allocation of 7 tons/year by 2021 by completing stream restoration project(s). This date is based on favorable initial feedback from two property owners.

All project(s) completed within the Swan Creek Watershed will also be credited towards the County's Chesapeake Bay stormwater wasteload allocation and the County's MS4 20% impervious restoration requirement. Any areas identified for potential restoration but not required to meet the Swan Creek wasteload allocation will be included within the County's inventory of capital improvement projects and prioritized across the County's watersheds.

While the County anticipates successful improvements to the streams proposed for restoration, the County's allocation only accounts for 18% of the overall project reduction necessary to meet the Sediment TMDL. Additionally, other factors or pollutants could influence the actual improvements to the biological communities in this watershed.

Watershed Restoration Monitoring

Foster Branch

Year 3 Monitoring, Results, and Analysis

December | 2018

Prepared For

Harford County
Watershed Protection and Restoration
Department of Public Works
212 South Bond Street, 1st Floor
Bel Air, Maryland 21014

Prepared By

KCI Technologies, Inc.
936 Ridgebrook Road
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APPENDICES

1 Background and Objectives

Harford County Department of Public Works (DPW) commissioned a watershed action plan for the Foster Branch watershed. The Foster Branch Small Watershed Action Plan (BayLand 2013) was completed in January of 2013. The plan outlines restoration projects and storm-water retrofits throughout this approximately 1,400 acre watershed. In anticipation of the permit conditions which may be placed on these restoration projects by Maryland Department of the Environment (MDE) and the U.S. Army Corps of Engineers (USACE), a monitoring plan was developed for the Foster Branch watershed. KCI Technologies, Inc. (KCI) developed the Foster Branch Monitoring Plan (Harford County 2016) with sites located generally upstream and downstream of proposed or constructed restoration projects and completed the first and second years of monitoring in 2015-2016 and 2016-2017 respectively.

Monitoring of the Foster Branch sites began in the summer of 2015 and included three years of paired summer and spring sampling visits. Timings of these sampling events are summarized in Table 1. KCI completed the third year of chemical, physical, and biological stream sampling in spring of 2018 at the five stream sites described in the plan. This report describes the methods and results of the first, second, and third years of sampling conducted at the Foster Branch sites.

Table 1 – Monitoring Years

	Summer	Spring
Year 1	September 2015	April 2016
Year 2	August-September 2016	March 2017
Year 3	August 2017	March 2018

The primary goals of this effort are to characterize baseline stream conditions (biological, physical habitat, and in situ chemical) prior to additional restoration project/BMP implementation and assess any ecological uplift possibly attributable to implementation of restoration in the Foster Branch watershed. A secondary goal is to conduct monitoring in Foster Branch that can be used to document ecological uplift and habitat improvement as projects are completed within this watershed.

The monitoring effort includes chemical (*in situ* water quality), physical (habitat assessment), and biological (benthic macroinvertebrate, fish, herpetofauna, freshwater mussels, and crayfish) assessments conducted at each of the selected sites. The sampling methods used are consistent with Maryland Department of Natural Resources' (DNR) Maryland Biological Stream Survey (MBSS). The methods have been developed locally and are calibrated specifically to Maryland's ecophysiographic regions and stream types.

1.1 Sampling Sites

Five sampling sites were selected within the Foster Branch watershed (Figure 1) to characterize baseline stream conditions and to assess the effect of planned and completed restoration on the ecological health of the watershed. A brief description of sites follows, for more detailed information about each site see the *Foster Branch Monitoring Plan* (Harford County, 2016).

1.1.1 Fost-1

Site Fost-1 is located close to the head-of-tide near the downstream most point in the Foster Branch watershed. This site is co-located with the USGS stream gage on Foster Branch (01585075). A stream restoration was previously completed by Harford County at this location and Fost-1 is located wholly within the restored reach. The land use upstream of Fost-1 is mostly urban (65.7%) with most of the remaining portion in forest (31.3%). This site will integrate the effects of all future restoration projects in the watershed.

1.1.2 Fost-2

Fost-2 is located on east branch of Foster Branch a short distance upstream of Trimble Rd and the confluence with the west branch. This site is located within a future planned stream restoration project and downstream of the Dembytown stream restoration project completed in 2017. This site is the most urban of the Foster Branch sites, with 77.4% of the upstream watershed in urban and 22.1% in forest categories. This site will measure ecological response to all restoration projects on the east branch as they are implemented.

1.1.3 Fost-3

The site Fost-3 is located on the west branch of Foster Branch in a similar relative position as Fost-2, a short distance upstream of Trimble Rd and the confluence with the east branch. The west branch is the larger of the two branches of Foster Branch. This site is located a short distance downstream of both a planned stream restoration project and a planned sediment removal project. This site will integrate and assess the ecological benefit of all implemented restoration projects in the west branch.

1.1.4 Fost-4

This site is located on an unnamed tributary to the west branch, primarily draining forested (65.5%) land. This site has the smallest amount of urbanization (19.7% urban, approximately 2% impervious)) in its upstream drainage. Two large stream restoration projects are planned for the headwaters of this unnamed tributary. This site will measure ecological lift possibly attributable to stream restoration in a minimally developed subwatershed. The benthic macroinvertebrate community at Fost-4 was sampled each of the three monitoring years, while the fish community was sampled only in Year 1.

1.1.5 Fost-5

This site is located on an unnamed tributary to the west branch, primarily draining urban (55.2%) land. This site is much more urban than Fost-4, with approximately 29% of the upstream area in impervious land cover. This site is downstream of two planned stream restoration projects and one new stormwater BMP. This site will assess the ecological benefit of planned restoration in a heavily urbanized subwatershed. The County's 2014 impervious layer was used to assess imperviousness to each site. Site specific land use and impervious surface analysis was completed using drainage areas delineated to each sampling point. The benthic macroinvertebrate community at Fost-5 was sampled each of the three monitoring years, while the fish community was sampled only in Year 1.

2 Methods

2.1 Land Use and Impervious

Catchments delineating all land draining to each stream site were created in ESRI's ArcGIS 10.1.3 using topographic data from Harford County and midpoints of each site collected in the field using sub-1m accuracy Trimble GPS units paired with a tablet PC.

The resulting site catchments were then used to calculate land use and imperviousness for each site. The most recently available land use data (2010) for Harford County were obtained from Maryland Department of Planning. Impervious cover data sets included Harford County's planimetric impervious data from 2014 and the National Land Cover Dataset impervious estimate from 2011. Area of each land use category and impervious cover were calculated for each catchment and converted to a percent of the catchment.

2.2 Water Quality Sampling

Water quality conditions were measured *in situ* during the summer sampling visits at all Foster Branch sites. Currently the MBSS does not measure *in situ* water quality at sites, but did so in the past. *In situ* water quality methods used were consistent with those in DNR, 2010. Field measured parameters include temperature, dissolved oxygen, pH, specific conductance, and turbidity. Measurements at each site were made at the upstream end of the 75-meter long site. *In situ* measurements were made before any sampling activities started to avoid sampling water disturbed by other activities. Most *in situ* parameters (i.e., temperature, pH, specific conductivity, and dissolved oxygen) were measured using a multiparameter sonde (YSI Professional Plus), while turbidity was measured with a Hach 2100 Turbidimeter. Water quality meters are regularly inspected and maintained and were calibrated immediately prior to sampling to ensure proper usage and accuracy of the readings.

2.3 Physical Habitat Assessment

Each stream site was characterized based on visual observations of physical characteristics and various habitat parameters. The Maryland Biological Stream Survey's (MBSS) Physical Habitat Index (PHI; Paul et al., 2003) was used to assess the physical habitat at the site.

To reduce individual sampler bias, assessments were completed as a team with discussion and agreement of the scoring for each parameter. In addition to the visual habitat assessments, photographs were taken from three locations within each sampling reach (downstream end, midpoint, and upstream end) facing in the upstream and downstream direction, for a total of six (6) photographs per site.

The PHI incorporates the results of a series of habitat parameters selected for Coastal Plain, Piedmont and Highlands regions. While all parameters are rated during the field assessment, the Coastal Plain parameters were used to develop the PHI score for these sites because the Foster Branch watershed is located in Maryland's coastal plain ecophysiographic region. In developing the PHI, MBSS identified eight parameters that have the most discriminatory power for the coastal plain streams. These parameters are used in calculating the PHI (Table 2). Several of the parameters have been found to be drainage area dependent and are scaled accordingly. The drainage area to each site was calculated in GIS using the GPS-collected location of each site, streams and 2-foot contour data from Harford County.

Table 2 – PHI Coastal Plain Parameters

Coastal Plain Stream Parameters	
Instream Habitat	Epifaunal Substrate
Bank Stability	Percent Shading
Remoteness	Number Woody Debris/Root wads

Each habitat parameter is given an assessment score ranging from 0-20, with the exception of shading (percentage 0-100%) and woody debris and root wads (total count). A prepared score and scaled score (0-100) are then calculated. The average of these scores yields the final PHI score. The final scores are then ranked according to the ranges shown in Table 3 and assigned corresponding narrative ratings, which allows for a score that can be compared to habitat assessments performed statewide.

Table 3 – PHI Score and Ratings

PHI Score	Narrative Rating
81.0 – 100.0	Minimally Degraded
66.0 – 80.9	Partially Degraded
51.0 – 65.9	Degraded
0.0 – 50.9	Severely Degraded

2.1 Benthic Macroinvertebrate Sampling

Benthic macroinvertebrate collection strictly followed MBSS procedures (Stranko et al., 2015). Sampling occurred during the Spring Index Period (March 1 – April 30), samples were collected from all five Foster Branch sites on March 12, 2018. The monitoring sites consist of a 75-meter reach and benthic macroinvertebrate sampling is conducted once per year. The sampling methods utilize semi-quantitative field collection of the benthic macroinvertebrate community. The multi-habitat D-frame net approach is used to sample a range of the most productive habitat types present within the reach. Best available habitats include riffles, stable woody debris, root wads, root mats, leaf packs, aquatic macrophytes, and undercut banks. In this sampling approach, a total of twenty jabs (each approximately one square foot) are distributed proportionally among all best available habitats within the stream site, combined into a single composite sample, and preserved in 95 percent ethanol. The composite sample contains material collected from approximately 20 square feet of habitat.

MBSS specifies that a minimum of 5% (1 in 20) of sites are selected for a duplicate sample (Stranko et al., 2015). Because the total number of samples in this project (5) is well below 20, Foster Branch samples were pooled with other County monitoring project samples from Plumtree Run (5) to meet the field sampling QC objective (1 in 10, or 10.0%). The randomly selected QC site for 2018 was taken at a site in the Plumtree Run watershed, Plum-3.

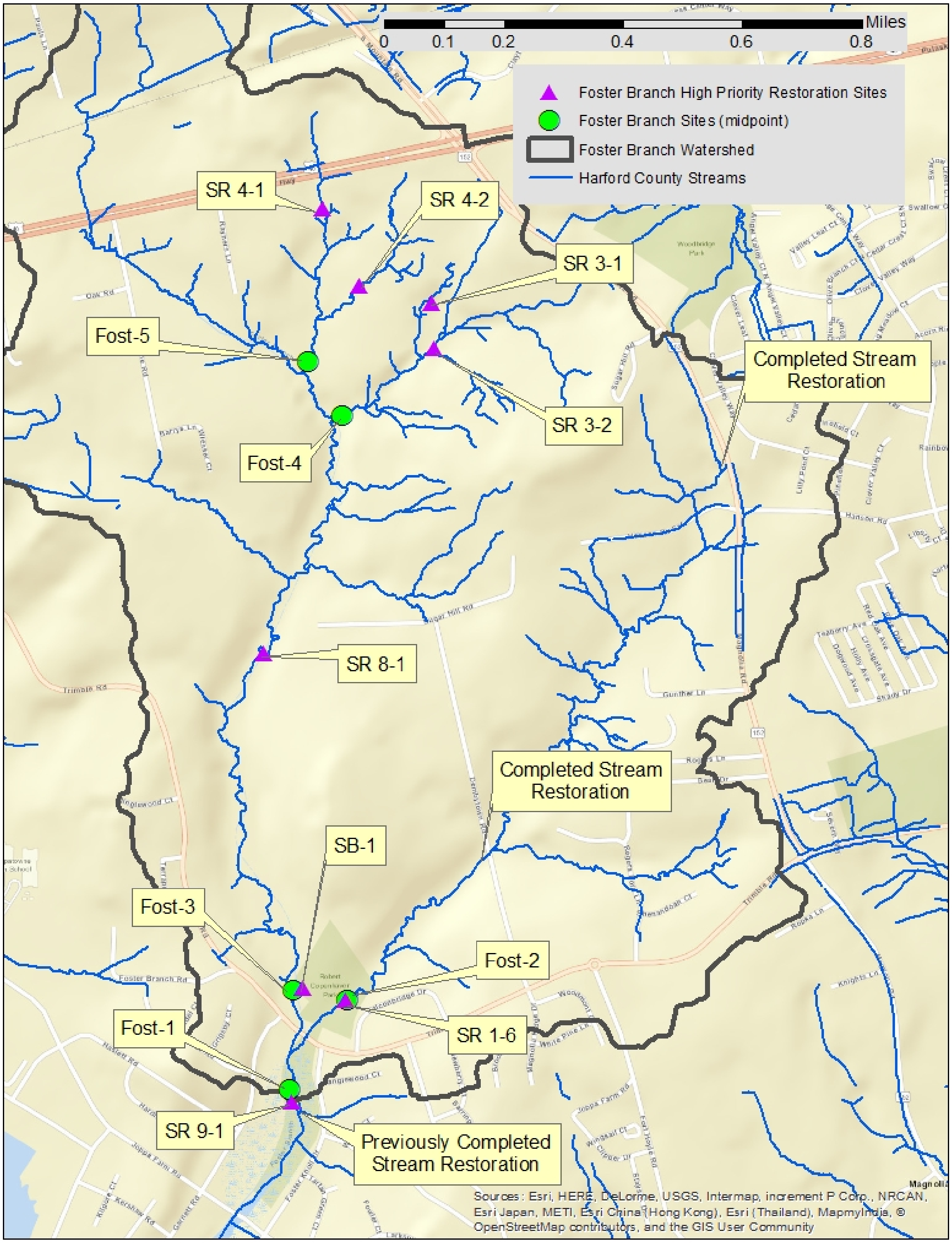

Figure 1 – Location of Sampling Sites

2.1.1 Benthic Macroinvertebrate Sample Processing and Laboratory Identification

Benthic macroinvertebrate samples were processed and subsampled according to methods described in the MBSS Laboratory Methods for Benthic Macroinvertebrate Processing and Taxonomy (Boward and Friedman 2011). Subsampling was conducted to standardize the sample size and reduce variation caused by samples of different size. In this method, the sample was spread evenly across a numbered, gridded tray (100 total grids), and a grid was picked at random and picked clean of organisms. If the organism count was 100 or more, then the subsampling was complete. If the organism count was less than 100, then another grid was selected at random and picked clean of organisms. This repeated until the organism count reached 100 to 120 organisms. The 100 (plus 20 percent) organism target is used to allow for specimens that are missing parts or are not mature enough for proper identification, are terrestrial, or meiofauna. Identification of the subsampled specimens was conducted by Environmental Services and Consulting, Inc. Taxa were identified to the genus level for most organisms. Groups including Oligochaeta and Nematomorpha were identified to the family level while Nematomorpha was left at phylum. Individuals of early instars or those that were damaged were identified to the lowest possible level, which could be phylum or order, but in most cases was family. Chironomidae could be further subsampled depending on the number of individuals in the sample and the numbers in each subfamily or tribe. Most taxa were identified using a stereoscope. Temporary slide mounts viewed with a compound microscope were used to identify Oligochaeta to family and for Chironomid sorting to subfamily and tribe. Permanent slide mounts were then used for Chironomid genus level identification. Results were logged on a bench sheet and entered into a spreadsheet for analysis.

Benthic macroinvertebrate lab quality control procedures followed those used by the MBSS (Boward and Friedman 2011). Because the total number of samples in this project (5) is well below 20, Foster Branch samples were pooled with samples from Plumtree Run (5) to meet the laboratory QC objective (1 in 10, or 10.0%). The lab QC samples were selected at random from either Foster Branch or Plumtree Run samples. One (1) sample was randomly selected for QC re-identification by an independent lab.

2.1.2 Benthic Macroinvertebrate Data Analysis

Benthic macroinvertebrate data were analyzed by KCI using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. The metrics selected fall into five major groups including taxa richness, composition measures, tolerance to perturbation, trophic classification, and habit measures. Raw values from each metric were given a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled IBI score from 1.0 to 5.0, and a corresponding narrative biological condition rating was applied.

Three sets of metric calculations have been developed for Maryland streams based on broad eco-physiographic regions. These include the Coastal Plain, Piedmont and combined Highlands. The study area is located in the Coastal Plain region therefore the following metrics (Table 4) and IBI scoring (Table 5) were used for the analysis.

Table 4 – Benthic Macroinvertebrate Metric Scoring for the Coastal Plain BIBI

Metric	Score		
	5	3	1
Total Number of Taxa	≥ 22	14 – 21	< 14
Number of EPT Taxa	≥ 5	2 – 4	< 2
Number of Ephemeroptera Taxa	≥ 2	1 – 1	< 1
% Intolerant to Urban	≥ 28	10 - 27	< 10
% Ephemeroptera	≥ 11	0.8 – 10.9	< 0.8
Number of Scraper Taxa	≥ 2	1 - 1	< 1
% Climbers	≥ 8	0.9 – 7.9	< 0.9

*Adjusted for catchment size

Table 5 – BIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

2.2 Fish Sampling

The fish community at each of the five Foster Branch sites was sampled during the Summer Index Period, June 1 through September 30, according to methods described in *Maryland Biological Stream Survey: Round Four Field Sampling Manual* (Stranko et al., 2015). In general, the approach uses two-pass electrofishing of the entire 75-meter study reach. Block nets were placed at the upstream and downstream ends of the reach, as well as at tributaries or outfall channels, to obstruct fish movement into or out of the study reach. Two passes were completed along the reach to ensure the segment was adequately sampled. The time in seconds for each pass was recorded and the level of effort for each pass was similar. Captured fish were identified to species and enumerated following MBSS protocols (Stranko et al., 2015). A total fish biomass for each electrofishing pass was measured. Unusual anomalies such as fin erosion, tumors etc., were recorded. Photographic vouchers were taken in lieu of voucher specimens.

2.2.1 Fish Data Analysis

Fish data for Foster Branch sites were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (DNR, 2005). The IBI approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. Raw values from each metric were assigned a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled FIBI score, ranging from 1.0 to 5.0, and a corresponding narrative rating of 'Good', 'Fair', 'Poor' or 'Very Poor' was applied, again in accordance with standard practice.

Four sets of FIBI metric calculations have been developed for Maryland streams based on DNR, 2005. These include the Coastal Plain, Eastern Piedmont, and warmwater and coldwater Highlands. Foster Branch is located in the Coastal Plain region, therefore, the following metrics listed in Table 6 were used for the FIBI scoring (Table 7) and analysis.

Table 6 – Fish Metric Scoring for the Coastal Plain FIBI

Metric	Score		
	5	3	1
Abundance per square meter	≥ 0.72	0.45 – 0.71	< 0.45
Number of Benthic species *	≥ 0.22	0.01 – 0.21	0
% Tolerant	≤ 68	69 – 97	> 97
% Generalist, Omnivores, Invertivores	≤ 92	93 - 99	100
% Round-bodied Suckers	≥ 2	1	0
% Abundance of Dominant Taxa	≤ 40	41 - 69	< > 69

*Adjusted for catchment size

Table 7 – FIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

2.3 Herpetofauna Survey

Herpetofauna (i.e., reptiles and amphibians) were surveyed at each of the five Foster Branch sites using methods following MBSS protocols (Stranko et al., 2015); 1) incidental collection, and 2) a search within all suitable stream salamander habitats within the 75-meter site. All collected individuals were identified to species level and released. Photographic vouchers were collected if a specimen could not be positively identified in the field.

Herpetofauna data collection occurs primarily to assist MBSS with supplementing their inventory of biodiversity in Maryland's streams. Currently, MBSS has not developed any indexes of biotic integrity for herpetofauna, and therefore, they were not used to evaluate the biological integrity of sampling sites throughout this study. Rather, the data are provided to help document existing conditions.

2.4 Freshwater Mussel Survey

A survey of freshwater mussels was conducted at each site using MBSS protocols (Stranko et al., 2015). Any live individuals encountered were identified, photographed, and then returned back to the stream as closely as possible to where they were collected. Any dead shells were retained as voucher specimens.

2.5 Crayfish Survey

Crayfish were surveyed at each site using MBSS protocols (Stranko et al., 2015). All crayfish observed while electrofishing were captured and retained until the end of each electrofishing pass. Captured crayfish were identified to species and counted before release back into the stream outside of the 75-meter sampling reach. Any crayfish encountered outside of the electrofishing effort were identified and noted on the datasheet as an incidental observation. Any crayfish burrows observed in and around the sampling site were excavated and an attempt made to capture the burrowing crayfish.

2.6 Invasive Plant Survey

A survey of invasive plants was performed at each site during the Summer Index Period following MBSS protocols (Stranko et al., 2015). The common name and relative abundance of invasive plants (i.e., present or extensive) within view of the study reach and within the 5-meter riparian vegetative zone parallel the stream channel were recorded.

Invasive plant data collection occurs to assist MBSS with supplementing their inventory of biodiversity. The data are provided to help document existing conditions at each site.

2.7 Quality Assurance and Quality Control

All work was conducted with thorough quality assurance and quality control. Biological assessment methods have been designed to be consistent and comparable with the methods used by MBSS (Stranko et al., 2015). Field crews receive yearly training in MBSS protocols and certification by DNR to perform benthic macroinvertebrate and fish sampling procedures. The Certified Fish Sampling Field Crew Leader and Fish Taxonomist for this project was Andy Becker. All field forms are checked and signed by the Crew Leader before leaving the site. Digital data entry is also checked for accuracy. Field equipment are checked regularly and calibrated as necessary prior to use. Calculation of metric scores and IBIs are completed using KCI's controlled and verified spreadsheet and each site undergoes a documented quality control check.

3 Results

Biological monitoring and water quality sampling were conducted to assess the conditions in the Foster Branch watershed. Presented below are the summary results for each monitoring component.

3.1 Land Use

The results of the land use analysis and impervious for Harford County and NLCD are presented below in Table 8.

Table 8 – Land Use and Imperviousness of Foster Branch Sites

Site	Urban	Agriculture	Forest	Other	Harford Co Impervious	NLCD Impervious
Fost-1	65.7%	1.5%	31.3%	1.5%	14.70%	5.90%
Fost-2	77.4%	0.4%	22.1%	0.1%	12.69%	2.98%
Fost-3	57.4%	2.3%	38.0%	2.4%	15.02%	8.06%
Fost-4	19.7%	0.0%	65.5%	14.9%	12.12%	4.62%
Fost-5	55.2%	0.0%	44.8%	0.0%	32.27%	22.61%

3.2 Water Quality

Water quality measurements were collected during the Summer Index Period sampling visit at each of the five Foster Branch sites. Table 9 presents the results of the *in situ* water quality measurements for Year 1 (summer 2015), Year 2 (summer 2016), and Year 3 (summer 2017).

Table 9 – In Situ Water Quality Measurement Results

Site	Season	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductance (µS/cm)	Turbidity (NTU)
Fost-1	Summer 2015	19.0	8.46	6.96	269.0	3.88
Fost-1	Summer 2016	22.0	8.86	6.92	325.6	20.9
Fost-1	Summer 2017	21.9	7.4	7.26	257.9	17.7
Fost-2	Summer 2015	17.2	2.13	6.57	224.2	6.47
Fost-2	Summer 2016	20.0	1.24	6.39	282.3	10.4
Fost-2	Summer 2017	20.8	5.96	6.87	222.8	66.2
Fost-3	Summer 2015	19.4	8.36	6.86	260.4	4.63
Fost-3	Summer 2016	18.2	7.91	6.90	247.5	4.82
Fost-3	Summer 2017	20.1	7.29	7.12	292.9	6.45
Fost-4	Summer 2015	18.0	6.35	6.83	112.4	10.1
Fost-5	Summer 2015	17.1	8.76	7.48	617.0	1.44

Shaded cells indicate values outside of the acceptable water quality criteria range or published values

MDE has established acceptable water quality standards for each designated Stream Use Classification, which are listed in the *Code of Maryland Regulations (COMAR) 26.08.02.03-.03 - Water Quality*. Foster Branch is covered in *COMAR* in Sub-Basin 02-13-08: Gunpowder River Area as Use I waters. Specific designated uses for Use I streams include growth and propagation of fish and aquatic life, water supply for industrial and agricultural use, water contact sports, fishing, and leisure activities involving direct water contact.

The acceptable criteria for Use I waters are as follows:

- pH - 6.5 to 8.5
- DO - may not be less than 5 mg/l at any time
- Turbidity - maximum of 150 Nephelometric Turbidity Units (NTU's) and maximum monthly average of 50 NTU
- Temperature - maximum of 90°F (32°C) or ambient temperature of the surface water, whichever is greater

In situ water quality measurements for temperature, pH, and turbidity for 2015, 2016, and 2017 were within COMAR standards for Use I streams with the exception of Fost-2 in 2016 with a pH value of 6.39. Measurement of dissolved oxygen at Fost-2 was 2.13 mg/L during the 2015 visit and 1.24 mg/L during the 2016 visit, below the Use I instantaneous criterion of 5.0 mg/L. The cause of the low dissolved oxygen measurement was likely due to the flow at this site being greatly reduced, the site was reduced to standing pools at the time of sampling during both 2015 and 2016 while in 2017 the stream was flowing and the dissolved oxygen was measured at 5.96 mg/L. With no flow to bring oxygenated water into the site, biological processes had likely reduced the dissolved oxygen available in what little water existed in the site. Although MDE does not have a water quality standard for specific conductivity, Morgan and others (Morgan et al, 2007; Morgan et al, 2012) have reported critical values for specific conductance in Maryland streams, above which there is a potential for detrimental effects on the stream biological communities. For the benthic macroinvertebrate community that critical value is 247 µS/cm, and for the fish community it is 171 µS/cm. Four of the five Foster Branch stream sites had specific conductivity value exceeding the threshold for fish community impairment, and exceedances were measured at these four sites during all *in situ* sampling events. Four of the five also had values exceeding the benthic macroinvertebrate threshold, with Fost-1 and Fost-3 exceeding during all three years, Fost-2 exceeding only during 2016, and Fost-5 exceeding during its only sampling event in 2015. Only Fost-4 had specific conductivity below both thresholds. Conductivity levels in this watershed are likely influenced by runoff from impervious surfaces (i.e., roads, sidewalks, parking lots, roof tops). Increased stream inorganic ion concentrations (i.e., conductivity) in urban systems typically results from paved surface de-icing, accumulations in storm-water management facilities (Casey et al., 2013), runoff over impervious surfaces, passage through pipes, and exposure to other infrastructure (Cushman, 2006). While elevated conductivity may not directly affect stream biota, its constituents (e.g., chloride, metals, and nutrients) may be present at levels that can cause biological impairment.

3.3 Physical Habitat Assessment

The summary results of the PHI habitat assessments are presented in Table 10. Fost-1, Fost-2 and Fost-3 all have compromised physical habitat, with PHI ratings of either 'Degraded' or 'Severely Degraded' with the exception of Fost-3 during Summer 2016 being rated as 'Partially Degraded'. Fost-4 and Fost-5 had the best habitat scores of the five sites scoring ('Partially Degraded' and 'Minimally Degraded', respectively), reflecting their location in a minimally-disturbed tract of forest. The relatively low habitat scores at Fost-1, Fost-2 and Fost-3 are likely due to urbanization effects on streams. Complete physical habitat data for each site are included in Appendix A.

Table 10 – PHI Habitat Assessment Results

Site	Season	PHI Score	PHI Narrative Rating
Fost-1	Summer 2015	50.0	Severely Degraded
Fost-1	Summer 2016	58.1	Degraded
Fost-1	Summer 2017	58.9	Degraded
Fost-2	Summer 2015	53.3	Degraded
Fost-2	Summer 2016	54.8	Degraded
Fost-2	Summer 2017	64.5	Degraded
Fost-3	Summer 2015	60.1	Degraded
Fost-3	Summer 2016	74.8	Partially Degraded
Fost-3	Summer 2017	63.1	Degraded
Fost-4	Summer 2015	78.6	Partially Degraded
Fost-5	Summer 2015	84.9	Minimally Degraded

3.4 Benthic Macroinvertebrate Community

The results of benthic macroinvertebrate community assessments for Year 3 are presented in Table 11. Complete benthic macroinvertebrate data for each site are included in Appendix B.

Table 11 – Benthic Index of Biotic Integrity (BIBI) Summary Data – Year 3

Metric	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Metric Values					
Total Number of Taxa	27	16	27	19	16
Number of EPT Taxa	3	1	2	4	2
Number of Ephemeroptera Taxa	0	0	0	0	0
% Intolerant to Urban	0.83	0.00	2.19	60.98	0.00
% Ephemeroptera	0.00	0.00	0.00	0.00	0.00
Number of Scraper Taxa	2	1	3	1	1
% Climbers	19.83	2.63	25.55	2.44	1.61
Metric Scores					
Total Number of Taxa	5	3	5	3	3
Number of EPT Taxa	3	1	3	3	3
Number of Ephemeroptera Taxa	1	1	1	1	1
% Intolerant to Urban	1	1	1	5	1
% Ephemeroptera	1	1	1	1	1
Number of Scraper Taxa	5	3	5	3	3
% Climbers	5	3	5	3	3
BIBI Score	***3.00***	***1.86***	***3.00***	***2.71***	***2.14***
Narrative Rating	***Fair***	***Very Poor***	***Fair***	***Poor***	***Poor***

Foster Branch sites had BIBI ratings for Year 3 ranging from the 'Very Poor' to 'Fair' category. Fost-1 and Fost-3 had the highest scores of 3.00 resulting in a 'Fair' rating. Fost-2 received the lowest score of 1.86 resulting in a rating of 'Very Poor'. Fost-4 and Fost-5 were both rated as 'Poor' with scores of 2.71 and 2.14 respectively. During Year 1, all sites except for Fost-4 had measured specific conductivity values greater than the published impairment threshold for benthic macroinvertebrates. Conversely, Fost-4 had the lowest measured specific conductivity and the highest proportion of organisms intolerant to urbanization. That pattern held true for Years 2 and 3 as well. A comparison of BIBI scores across the three years of monitoring is presented in Table 12 and Figure 2. BIBI scores in Year 3 were higher at Fost-1 and Fost-3, the same at Fost-4 and then lower at Fost-2 and Fost-5 when compared to Year 2.

Table 12 – BIBI Scores and Narrative Rating for all Years

Site	Year	BIBI Score	Narrative Rating
Fost-1	1 (Spring 2016)	2.14	Poor
Fost-1	2 (Spring 2017)	2.71	Poor
Fost-1	3 (Spring 2018)	3.00	Fair
Fost-2	1 (Spring 2016)	2.14	Poor
Fost-2	2 (Spring 2017)	2.14	Poor
Fost-2	3 (Spring 2018)	1.86	Very Poor
Fost-3	1 (Spring 2016)	3.00	Fair
Fost-3	2 (Spring 2017)	2.71	Poor
Fost-3	3 (Spring 2018)	3.00	Fair
Fost-4	1 (Spring 2016)	2.43	Poor
Fost-4	2 (Spring 2017)	2.71	Poor
Fost-4	3 (Spring 2018)	2.71	Poor
Fost-5	1 (Spring 2016)	1.86	Very Poor
Fost-5	2 (Spring 2017)	2.71	Poor
Fost-5	3 (Spring 2018)	2.14	Poor

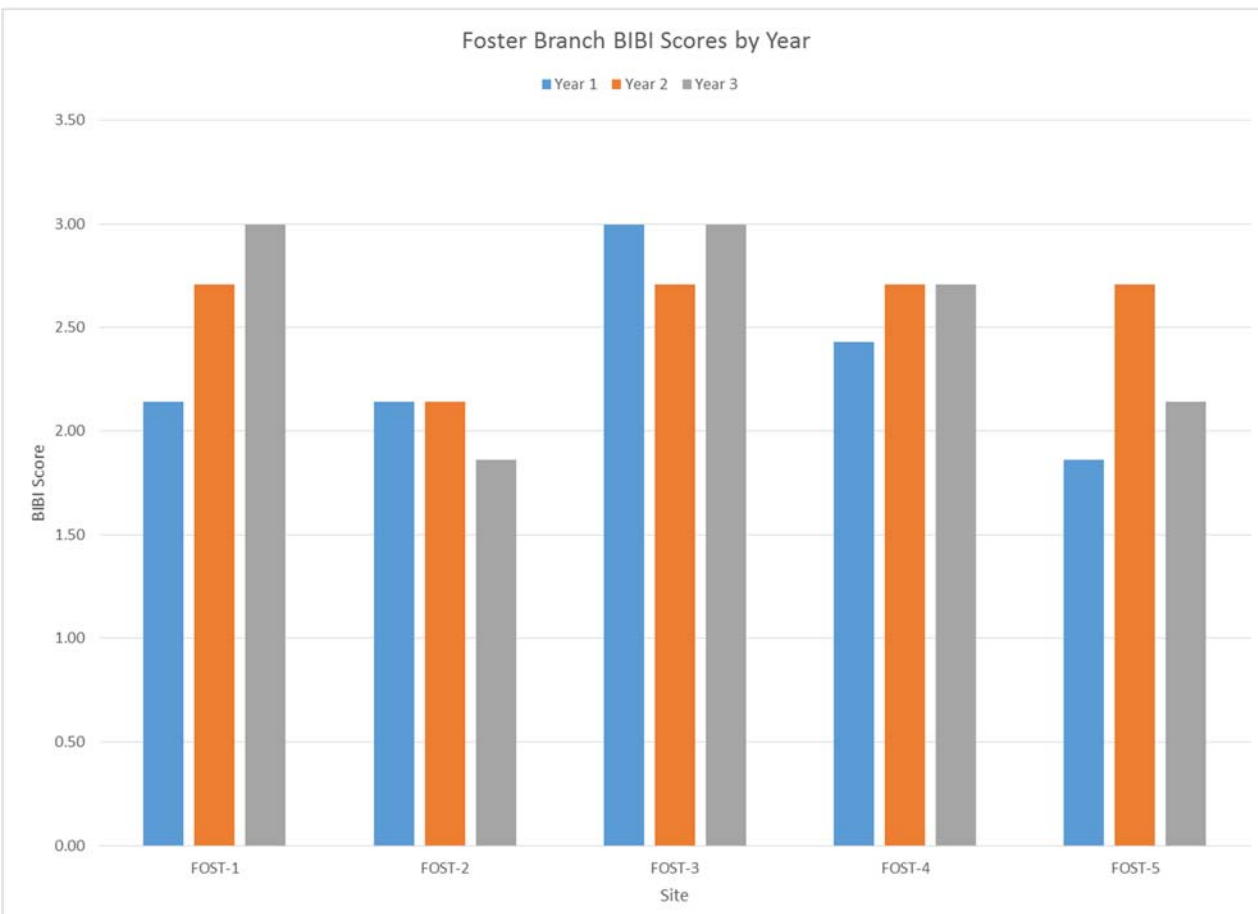

Figure 2 – BIBI Scores by Year

3.5 Fish Community

The results of the fish community assessments are presented in Table 13 and a cumulative list of species collected over all three sampling years at each site can be found in Table 14. Complete fish community data for each site are included in Appendix C.

Table 13 – Fish Index of Biotic Integrity (FIBI) Summary Data – Year 3

Metric	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Metric Values					
Abundance per square meter	1.84	0.31	1.86	n/a	n/a
Adjusted Number of Benthic species	1.37	0.00	1.67	n/a	n/a
% Tolerant	80.47	98.25	70.52	n/a	n/a
% Generalist, Omnivores, Invertivores	93.41	100.00	85.82	n/a	n/a
% Round-bodied Suckers	4.94	0.00	0.00	n/a	n/a
% Abundance of Dominant Taxon	24.71	5.26	44.78	n/a	n/a
Metric Scores					
Abundance per square meter	5	1	5	n/a	n/a
Adjusted Number of Benthic species	5	1	5	n/a	n/a
% Tolerant	3	1	3	n/a	n/a
% Generalist, Omnivores, Invertivores	3	1	5	n/a	n/a
% Round-bodied Suckers	5	1	1	n/a	n/a
% Lithophilic Spawners	5	5	3	n/a	n/a
FIBI Score	***4.33***	***1.67***	***3.67***	***n/a***	***n/a***
Narrative Rating	***Good***	***Very Poor***	***Fair***	***n/a***	***n/a***

Table 14 – Cumulative List of Fish Species Collected at Foster Branch Sites

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Least Brook Lamprey	*Lampetra aepyptera*	X		X		
Sea Lamprey	*Petromyzon marinus*			X		
American Eel	*Anguilla rostrata*	X		X		X
Eastern Mosquitofish	*Gambusia holbrooki*	X				
Brown Bullhead	*Ameiurus nebulosus*	X				
Creek Chubsucker	*Erimyzon oblongus*	X				
Northern Hogsucker	*Hypentelium nigricans*	X				
White Sucker	*Catostomus commersonii*	X		X		
Eastern Silvery Minnow	*Hybognathus regius*	X				
Rosyside Dace	*Clinostomus funduloides*	X		X		X
Satinfin Shiner	*Cyprinella analostana*	X		X		
Spottail Shiner	*Notropis hudsonius*	X				
Creek Chub	*Semotilus atromaculatus*	X	X	X	X	X
Blacknose Dace	*Rhinichthys atratulus*	X	X	X	X	X
Banded Killifish	*Fundulus diaphanus*	X		X		
Mummichog	*Fundulus heteroclitus*	X	X	X		X
Tessellated Darter	*Etheostoma olmstedi*	X		X		
Largemouth Bass	*Micropterus salmoides*	X		X		

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Bluespotted Sunfish	*Enneacanthus gloriosus*	X				
Lepomis sp.	*Lepomis sp.*	X				
Redbreast Sunfish	*Lepomis auritus*	X		X		
Bluegill	*Lepomis machrochirus*	X				
Pumpkinseed	*Lepomis gibbosus*	X	X	X		

The Foster Branch sites had FIBI ratings ranging across the entire spectrum from ‘Very Poor’ to ‘Good’.

Site Fost-1 had the highest FIBI score of all sites with, 4.33 which rated ‘Good’. Nineteen species of fish were collected during Year 3 at Fost-1, the highest diversity of the five sites. The diversity of fish collected at this site helped to drive the FIBI score into the ‘Good’ category. Larger stream sites along the Fall Line between Maryland’s Piedmont and Coastal Plain have a larger potential pool of species, possibly being occupied by species more commonly associated with one or the other physiographic provinces.

Fost-2 had a FIBI that scored the lowest of the five sites during Year 3, 1.67 or ‘Very Poor’, which is the lowest possible score. Only four species were collected during Year 3 sampling. This site was previously only standing pools during both the summer of 2015 and 2016, which reducing greatly the space and resources available to stream fish. In 2017 the entire site had flow going through it which aided in the increase in FIBI score. The ecological condition at this site is likely affected both by a lack space and habitat, and by poor water quality.

Site Fost-3 scored a 3.67 which was in the ‘Fair’ category. This site had fourteen species collected during sampling. While less diverse than Fost-1, the metrics scored well because of the smaller drainage area.

Neither Fost-4 nor Fost-5 were sampled during Years 2 or 3. These sites are small headwater streams which were outlined in the Foster Branch Monitoring Plan as being sampled less frequently as the rest of the Foster Branch sites.

A comparison of FIBI scores across the three years of monitoring is presented in Table 15 and Figure 3. Sites Fost-4 and Fost-5 were only sampled during Year 1 so comparison across years is not possible for these sites. Fost-1 had a slightly lower FIBI score (+0.67) in Year 3, a 4.33 compared to a 5.00. Fost-2 scored a 1.67, an increase of (+0.67) from both Year 1 and Year 2. During the first two years of sampling at Fost-2 the site was reduced to standing pools. This lack of water and habitat space likely is the cause of the low FIBI scores at this site. Site Fost-3 had a higher FIBI score (+0.34) in Year 3 than in Year 2, a 3.67 vs a 3.33.

Table 15 – FIBI Scores and Narrative Rating Across Years

Site	Year	FIBI Score	Narrative Rating
Fost-1	1 (Summer 2015)	4.67	Good
Fost-1	2 (Summer 2016)	5.00	Good
Fost-1	3 (Summer 2017)	4.33	Good
Fost-2	1 (Summer 2015)	1.00	Very Poor
Fost-2	2 (Summer 2016)	1.00	Very Poor
Fost-2	3 (Summer 2017)	1.67	Very Poor
Fost-3	1 (Summer 2015)	4.33	Good
Fost-3	2 (Summer 2016)	3.33	Fair
Fost-3	3 (Summer 2017)	3.67	Fair
Fost-4	1 (Summer 2015)	1.67	Very Poor
Fost-5	1 (Summer 2015)	2.67	Poor

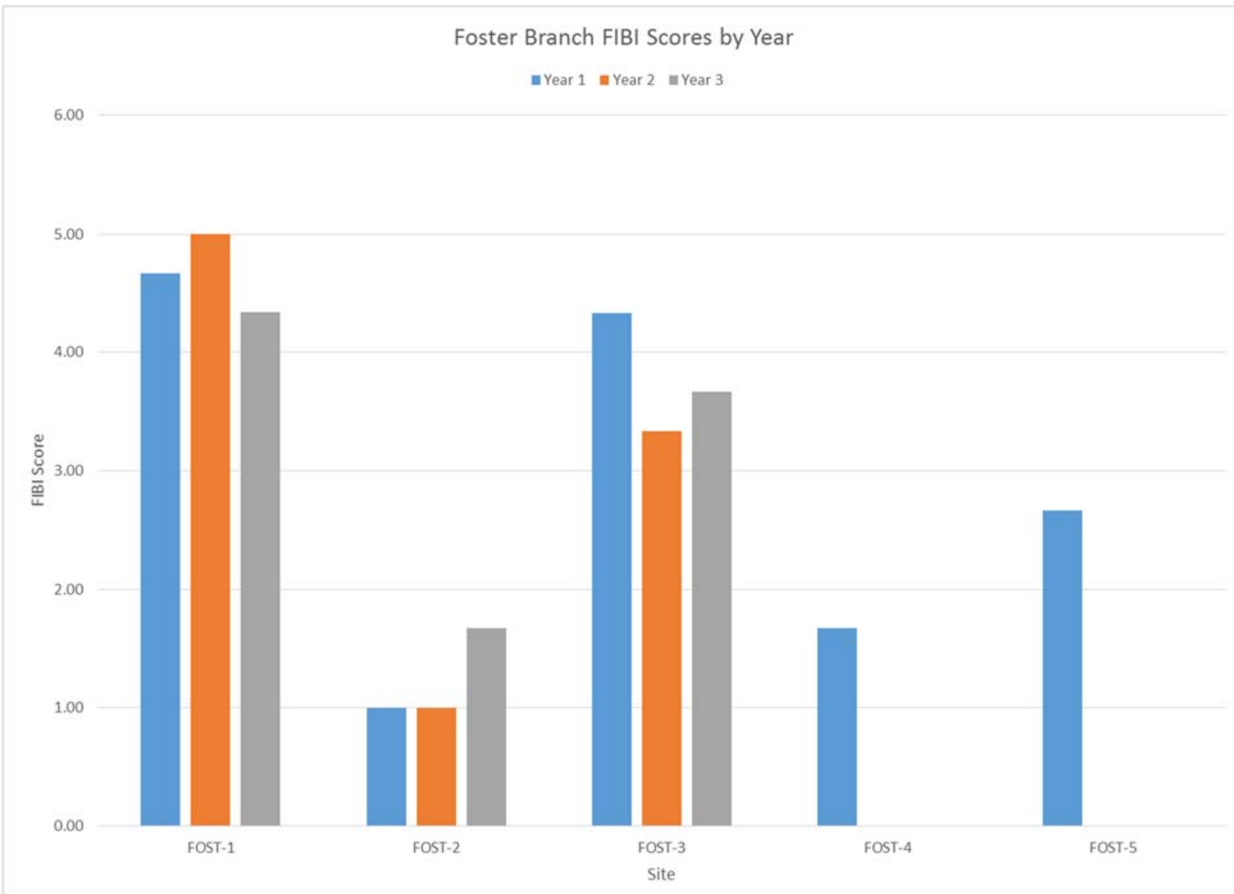

Figure 3 – FIBI Scores by Year

3.6 Herpetofauna

At least two amphibian species were collected at each of the sites (Table 16). Fost-1 has the highest diversity with five species present at the site. The most widely distributed species was Northern Green Frog, which was present at all five of the Foster Branch sites. Stream salamander species were observed at three of the five sites during the stream salamander search or incidentally during other sampling activities. Northern Two-lined Salamander was observed at Fost-2 during the summer 2015 field visit, at Fost-1 during the summer 2016 visit, and at Fost-5 during both summer 2015 and summer 2016. At Fost-1 and Fost-2 a single individual was captured during electrofishing activities, but none were observed during the targeted stream salamander search. At Fost-5 one individual was observed while electrofishing during the summer 2015 sampling event but no salamanders were encountered during the targeted stream salamander search. During summer of 2016 no electrofishing took place at Fost-5 but one individual was encountered during the stream salamander search. During summer 2017, no salamanders were encountered incidentally or during the stream salamander search.

Table 16 – Cumulative Herpetofauna Presence at Foster Branch Sites

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Cope's Gray Treefrog	*Hyla chrysoscelis*			X	X	
American Bullfrog	*Lithobates catesbeianus*	X				
Northern Green Frog	*Lithobates clamitans melanota*	X	X	X	X	X
Pickerel Frog	*Lithobates palustris*	X	X	X		
Northern Spring Peeper	*Pseudacris crucifer*	X				
Stream Salamanders						
Northern Two-lined Salamander	*Eurycea bislineata*	X	X			X

The low density of stream salamanders at three sites, and lack of stream salamanders at two of the five sites is likely due to a combination of habitat degradation and water quality impairment. There was very little suitable stream salamander habitat present at those sites for the field crew to search. The restoration reach (Fost-1) contained several areas of armored banks and rock structures in the stream. Those areas are not preferred habitat for stream salamanders. The non-restored sites had a dominant substrate of sand which in not a preferred habitat of stream salamanders. Stream salamanders generally prefer large cover objects over loose cobble and gravel, creating a moist microclimate and many interstices for shelter and foraging. Stream salamanders breathe through their highly permeable skin and are therefore particularly sensitive to water quality impairments. The high conductivity values suggest that salamanders would experience osmotic difficulties in these conditions.

3.7 Freshwater Mussels

No freshwater mussels were observed at any Foster Branch site during the three years of sampling. The lack of freshwater mussels at these sites is likely due to a combination of habitat degradation and water quality impairment. Freshwater mussels are relatively sessile organisms which live partially embedded within the stream substrates. The flashy hydrology characteristic of urban streams like Foster Branch create habitat conditions unsuitable for freshwater mussels. Also, it is likely that water quality conditions in urban streams are outside the range of tolerance of these sensitive organisms.

3.8 Crayfish

No crayfish were observed at three of the five Foster Branch sites. *Orconectes limosus*, a native species, was the only crayfish species observed at these sites and was observed at Fost-1 during electrofishing in all three years and at Fost-3 during Year 2 and Year 3. Crayfish burrows were observed at all of the Foster Branch sites during all three years of sampling. These burrows most likely were dug by *Cambarus diogenes*, but no specimens were collected to confirm. *Cambarus diogenes* is the most likely species as it is the only burrowing species collected by MD DNR in Harford County. The lack of crayfish may be due to habitat degradation. Both Fost-2 and Fost-3 had evidence of high flows, suggesting that flashy urban hydrology may frequently disturb cover objects reducing the availability of suitable crayfish habitat at those sites. Water quality conditions may also be impacting crayfish, but currently the water quality requirements for crayfish in Maryland are poorly understood.

3.9 Invasive Plant Species

Invasive plant species were present at all of the Foster Branch sites. Table 17 presents all invasive species found at each monitoring site cumulatively for all sampling visits. Fost-5 has the most invasive plant species with six, and Fost-4 had the least with two. Japanese stiltgrass was the most widely distributed invasive plant, found at all five sites. Oriental bittersweet and Multiflora rose were the next most widely distributed species, each being found at four sites.

Table 17 – Cumulative Invasive Plant Species Presence at Foster Branch Sites

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Garlic mustard	*Alliaria petiolata*		X			
Japanese barberry	*Berberis thunbergii*					X
Oriental bittersweet	*Celastrus orbiculatus*		X	X	X	X
Autumn olive	*Elaeagnus umbellata*			X		
Chinese Lespedeza	*Lespedeza cuneata*	X				
Japanese honeysuckle	*Lonicera japonica*		X			X
Japanese stiltgrass	*Microstegium vimineum*	X	X	X	X	X
Mile-a-minute	*Persicaria perfoilata*					X
Phragmites	*Phragmites sp.*	X				
Multiflora rose	*Rosa multiflora*	X	X	X		X

4 Analysis and Discussion

4.1 Annual Data

Data from all three years of the Foster Branch monitoring effort were compiled and analyzed to detect changes in condition over the three years of monitoring. Mean annual BIBI scores fluctuated during the three years of monitoring but the differences between years were not significant (Table 18, Figure 4). Mean annual FIBI scores for Foster Branch sites were generally higher and varied more than BIBI scores (Table 18, Figure 5). Differences in mean FIBI scores across years was not significant.

Table 18 – Mean BIBI and FIBI Scores by Year for Foster Branch Sites

	Year 1	Year2	Year 3
BIBI			
Mean	2.31	2.60	2.54
SD	0.433	0.255	0.518
FIBI			
Mean	2.87	3.11	3.22
SD	1.608	2.009	1.388

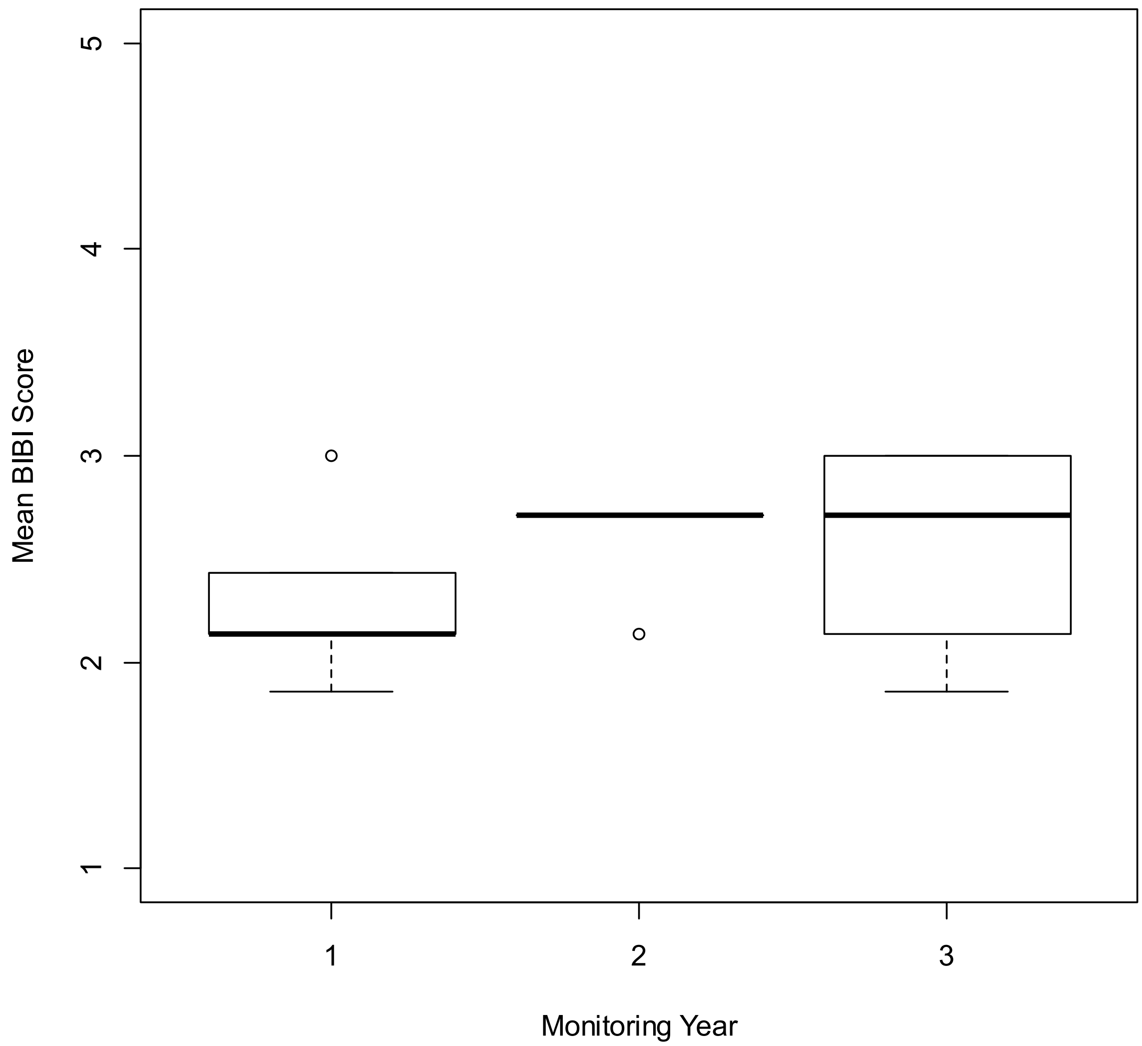

Figure 4 – Boxplots for Annual BIBI Scores for Foster Branch Sites

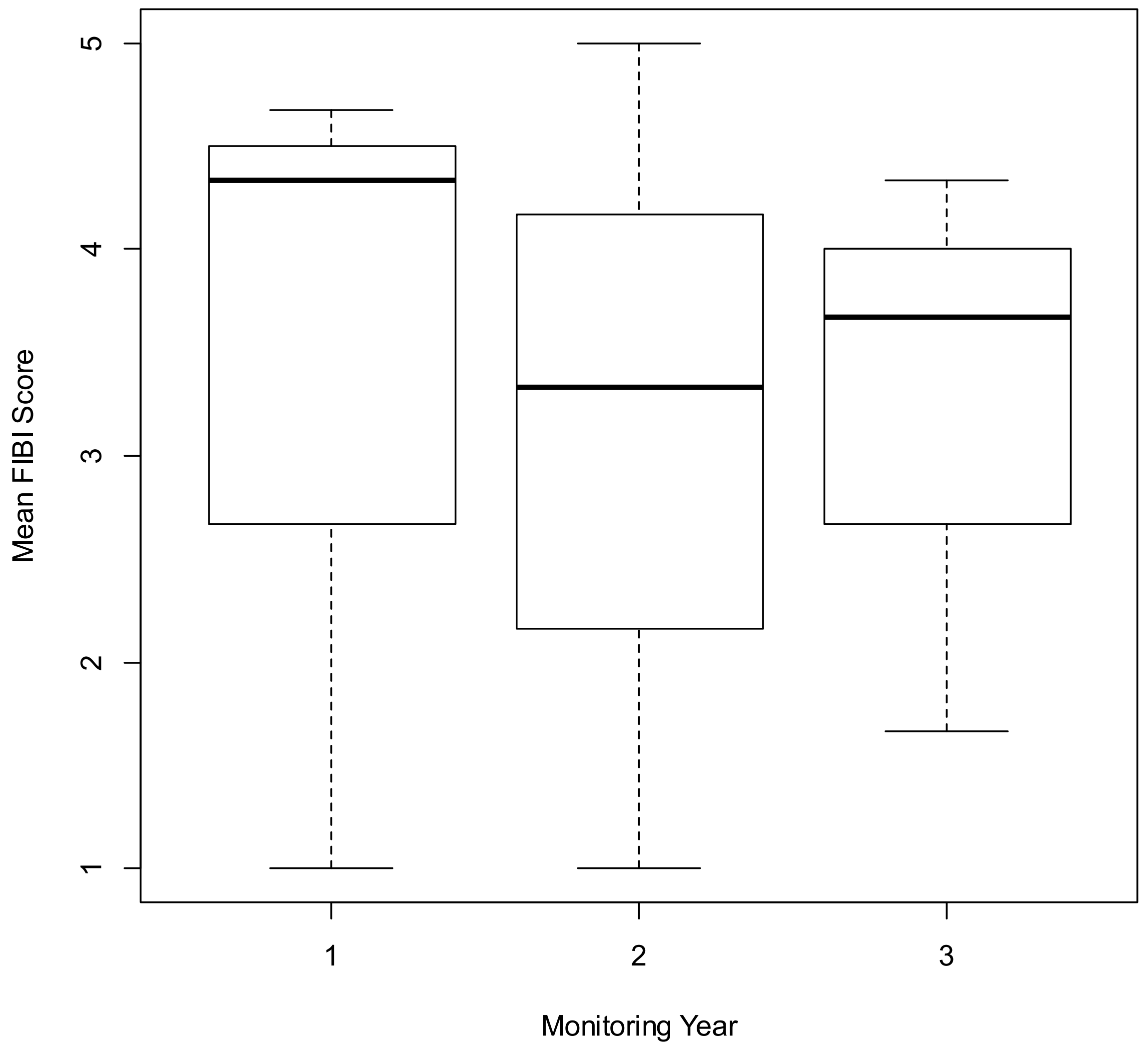

Figure 5 – Boxplots for Annual FIBI Scores for Foster Branch Sites

4.2 Comparison with MBSS Data

Data from the MBSS were obtained from MD DNR. Since Foster Branch is in the Coastal Plain strata used by MBSS, we selected only MBSS sites from the Coastal Plain for a comparative analysis. Impervious data from the 2011 NLCD was used for Foster Branch sites to remain consistent with impervious data used by MBSS. Three of the Foster Branch sites; Fost-2, Fost-4, and Fost-5; do not fall on the 1:100,000 scale stream file used by MBSS and are possibly smaller in watershed size than sites normally sampled by MBSS.

MBSS frequently cites higher urban land use, and impervious surfaces especially, result in lower BIBI in streams across Maryland. To relate the results from Foster Branch to ecological condition and possible stressors for other streams in Maryland, we compared Foster Branch results with MBSS Coastal Plain sites from 1995-2017.

Foster Branch BIBI scores were plotted with MBSS results against percent urban land use (Figure 6) and percent imperviousness (Figure 7). A regression analysis was performed on these same variables. Foster Branch BIBI scores showed a weak, negative, non-signifcant relationship with percent urban land use (R^2=0.10, p=0.25). There was also a weak, negative, non-signifcant relationship with percent imperviousness (R^2=0.02, p=0.59). When plotted with the distribution of MBSS Coastal Plain sites, we see that Foster Branch sites generally plot in the lower portion of the MBSS distribution for percent urban (Figure 6) and for percent imperviousness (Figure 7). This may be an indication that Foster Branch sites are more sensitive to the effects of urbanization than the average Coastal Plain stream. The low sample size (n=15) and non-significant regressions limit the conclusions that can be drawn from these data.

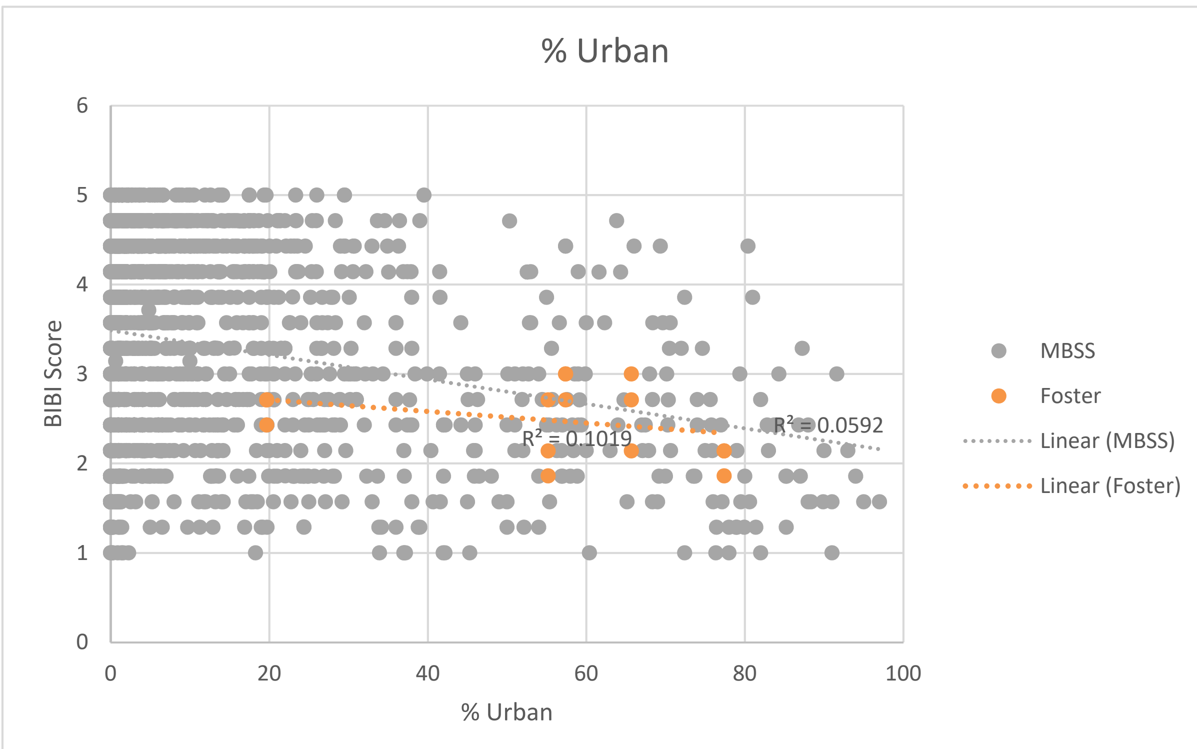

Figure 6 - BIBI score vs percent urban land use for Fosters Branch and MBSS (1995-2017) sampling sites

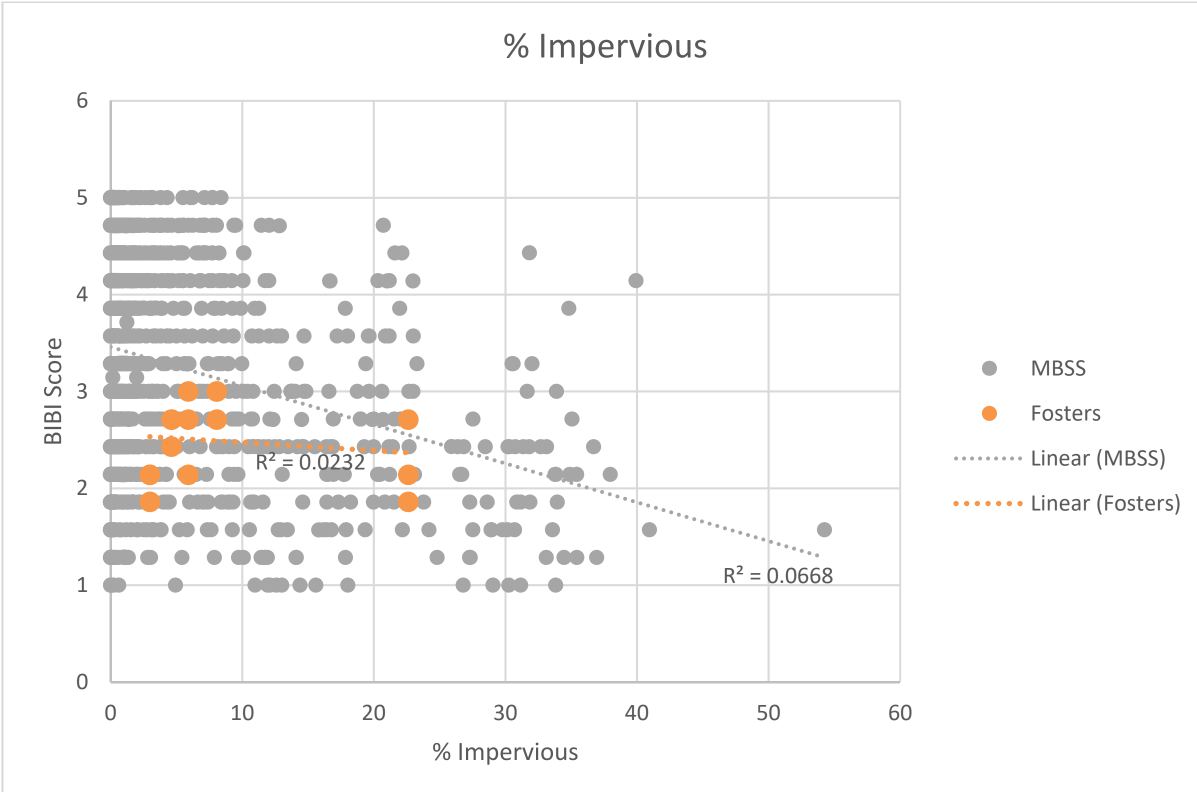

Figure 7 - BIBI score vs percent impervious land cover for Fosters Branch and MBSS (1995-2017) sampling sites

Foster Branch FIBI scores were also plotted with MBSS data against percent urban land use (Figure 8) and percent imperviousness (Figure 9). A regression analysis was performed on these variables. Foster Branch FIBI scores showed a weak, negative, non-significant relationship with percent urban land use (R^2=0.004, p=0.85). Surprisingly, there was a positive, but non-significant relationship with percent imperviousness (R^2=0.04, p=0.56). This is contrary to patterns seen in the larger state-wide MBSS dataset and our understanding of stream ecological response to urbanization. This regression is non-significant and should not be considered a possible pattern in fish community response to urbanization. When plotted with the distribution of MBSS Coastal Plain sites, we see that Foster Branch sites plot with no apparent pattern for fish community response when compared to the MBSS distribution for percent urban (Figure 8) and for percent imperviousness (Figure 9). One potential explanation could be that the smaller three Foster Branch sites not on the MBSS stream network are approaching the stream size limit for fish occupancy. A development of a species-area curve from MBSS data would help answer this question.

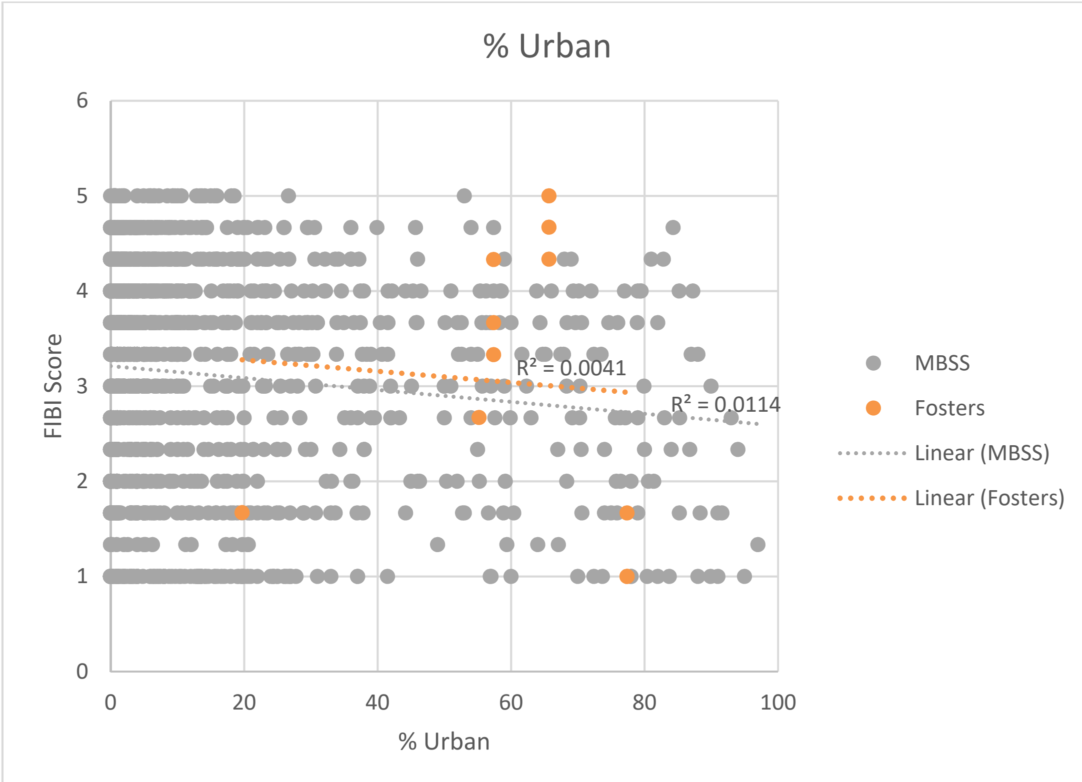

Figure 8 - FIBI score vs percent urban land use for Fosters Branch and MBSS (1995-2017) sampling sites

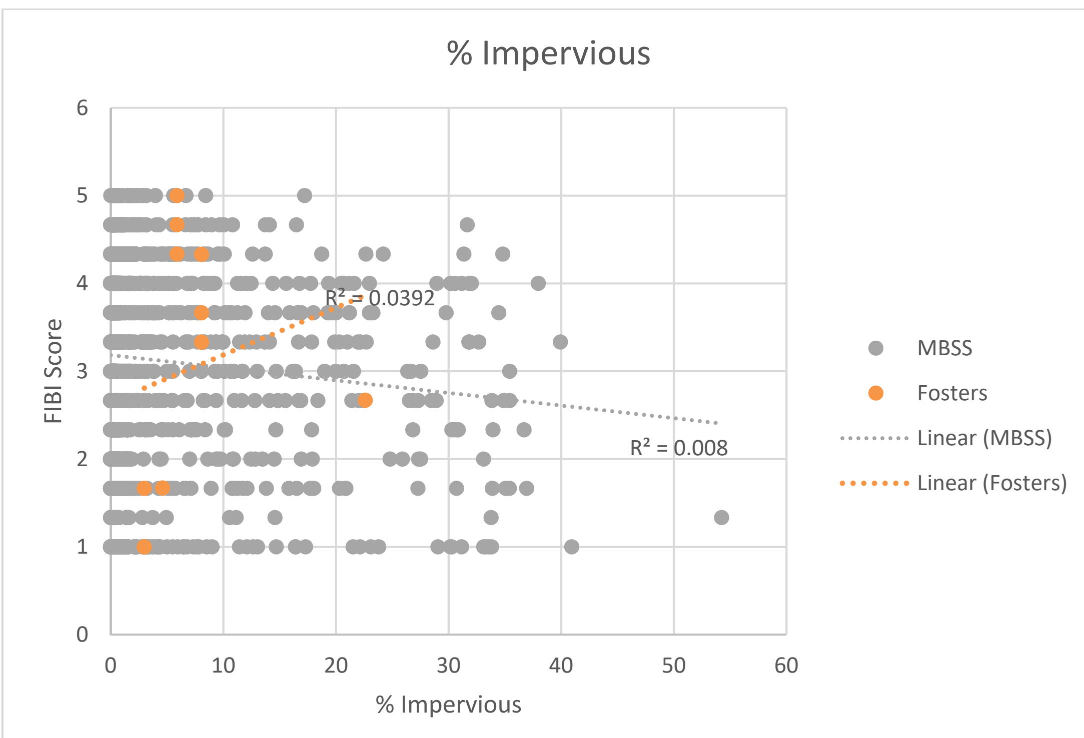

Figure 9 - FIBI score vs percent impervious land cover for Fosters Branch and MBSS (1995-2017) sampling sites

4.3 Conclusion

The Foster Branch watershed is urbanized like much of central Maryland. The ecological condition of the sites in Foster Branch show impaired benthic macroinvertebrate communities with degraded physical habitat and high conductivity values. The fish community at Fost-1, the most downstream site, generally has a higher FIBI score than the other Foster Branch sites, but the other sites are close to or below the threshold for community impairment. The high amount of urban land use and imperviousness likely result in higher, flashier storm flows that impact habitat quantity and quality, and result in high conductivity values from de-icing materials which cause lethal and sub-lethal effects on the freshwater organisms in Foster Branch. Over the three years of monitoring the mean IBI scores have not changed significantly and there are no observable trends in condition over this time. Harford County has plans to continue this monitoring in the future. Additional years of sampling will increase the number of samples and allow more sophisticated statistical analyses to detect changes in condition over time and as additional restoration projects are implemented.

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Plumtree Run

Year 3 Monitoring, Results, and Analysis

December | 2018

Prepared For

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APPENDICES

1 Background and Objectives

Harford County Department of Public Works (DPW) commissioned a watershed action plan for the Plumtree Run watershed. The Plumtree Run Small Watershed Action Plan (BayLand 2011) was completed in June of 2011. The plan outlines future restoration projects and storm-water retrofits throughout this approximately 1,650 acre watershed. In anticipation of the permit conditions which may be placed on these restoration projects by Maryland Department of the Environment (MDE) and the U.S. Army Corps of Engineers (USACE), a monitoring plan was developed for the Plumtree watershed with sites located generally upstream and downstream of proposed or constructed restoration projects and completed the first and second years of monitoring in 2015-2016 and 2016-2017 respectively (Table 1).

KCI Technologies, Inc. completed the third year of pre-implementation baseline chemical, physical, and biological stream sampling in spring of 2018 at the five stream sites described in the plan. This technical memorandum describes the methods and results of the three years of sampling conducted at those sites in the Plumtree Run watershed and an analysis of all three years' worth of data.

Table 1 – Monitoring Years

	Summer	Spring
Year 1	September 2015	April 2016
Year 2	August-September 2016	March 2017
Year 3	August 2017	March 2018

The primary goal of this effort is to characterize baseline stream conditions (biological, physical habitat, and in situ chemical) prior to additional restoration project/BMP implementation. A secondary goal is to conduct monitoring in Plumtree Run that can be used to document ecological uplift and habitat improvement as projects are completed within this watershed.

The monitoring effort includes chemical (in situ water quality), physical (habitat assessment), and biological (benthic macroinvertebrate, fish, herpetofauna, freshwater mussels, and crayfish) assessments conducted at each of the selected sites. The sampling methods used are consistent with Maryland Department of Natural Resources' (DNR) Maryland Biological Stream Survey (MBSS). The methods have been developed locally and are calibrated specifically to Maryland's ecophysiographic regions and stream types.

1.1 Sampling Sites

Five sampling sites were selected within the Plumtree Run watershed (Figure 1) to characterize baseline stream conditions and to assess the effect of planned restoration on the ecological health of the watershed. A brief description of sites follows, for more detailed information about each site see the *Plumtree Run Monitoring Plan* (Harford County 2016).

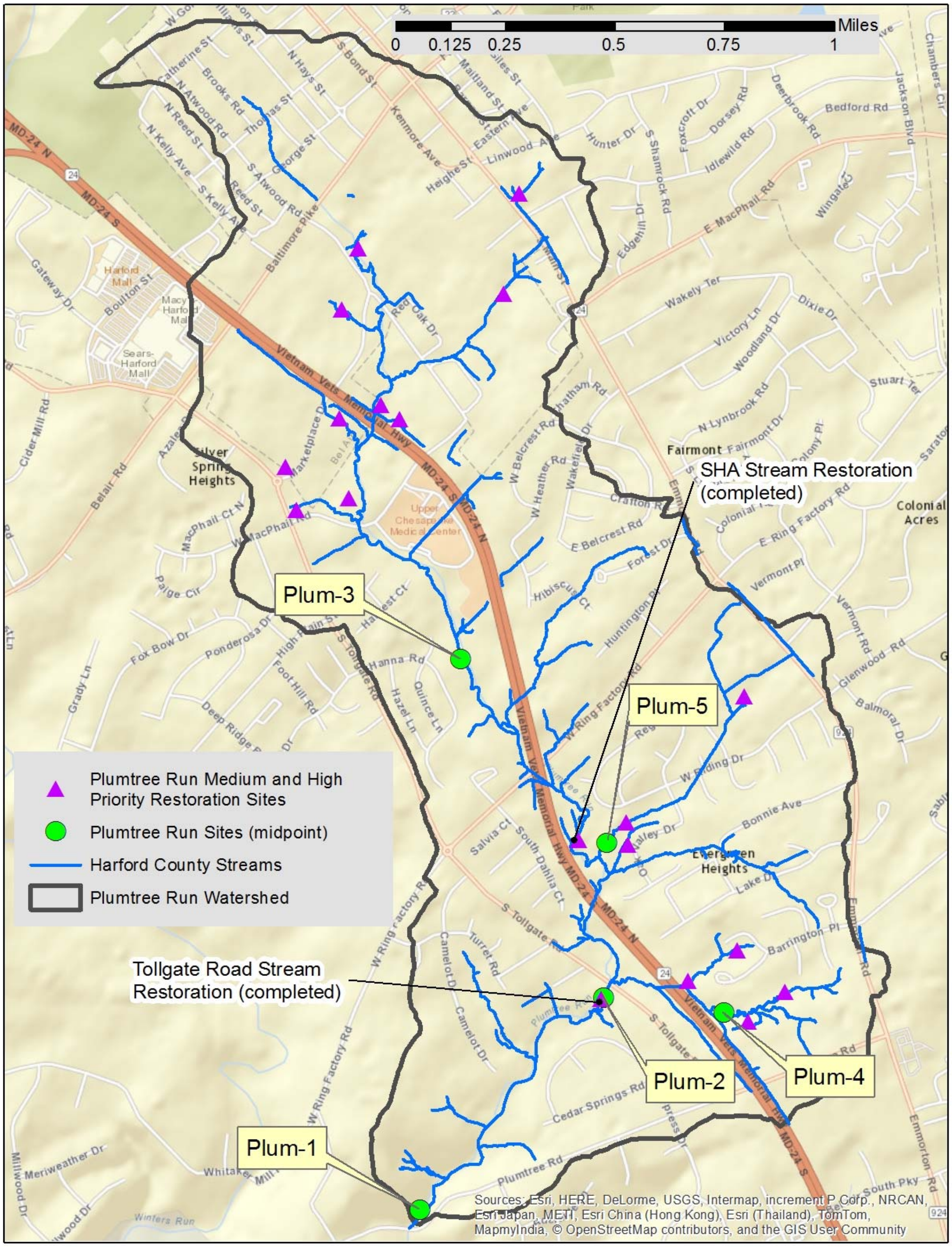

Figure 1 – Location of Sampling Sites

1.1.1 Plum-1

Site Plum-1 is the downstream-most site in the Plumtree Run watershed. This site is located on the mainstem of Plumtree Run in the area of the USGS gage at Plumtree Road. This site will be used to measure overall watershed response to the restoration treatments implemented within the watershed. Since this site is located so close to the USGS gage on Plumtree Run, future analysis of the relationships between biological parameters, stream flow, and water quality may be possible. The land use upstream of Plum-1 is mostly urban and suburban (87.9%) with the remaining portion in agriculture (7.2%) and forest (4.8%). This site will integrate the effects of all future restoration projects in the watershed.

1.1.2 Plum-2

Plum-2 is located on the mainstem of Plumtree Run downstream of Tollgate Road within a previously completed stream restoration reach. The catchment upstream of this site is mostly urban and suburban land (90.4%) with the remaining land classified as agriculture (5.8%) and forest (3.8%). This site will measure ecological response to all restoration projects upstream of this point as those projects are implemented. This site will also directly measure habitat and ecological lift at a previously restored reach downstream of Tollgate Road. Data collected at this site are all post-restoration of the Tollgate Road reach. This site is located approximately 420 meters downstream of a MBSS site (HA-P-151-10-96) sampled in 1996.

1.1.3 Plum-3

Plum-3 is located on the mainstem of Plumtree Run downstream of the political boundary of the Town of Bel Air. The upstream catchment to this site is mostly urban (93.5%) with the remaining land classified as agriculture (6.5%). This site will assess the ecological health of Plumtree Run as it enters Harford County's jurisdiction. It will also measure ecological response to future restoration as projects are implemented within the Town of Bel Air.

1.1.4 Plum-4

This site is located on an unnamed tributary to Plumtree Run, primarily draining urban (71.3%) land. The Plumtree Run plan identified extensive stream restoration and stormwater retrofit projects upstream of the site. This site will measure ecological lift possibly attributable to the planned restoration in this urbanized part of the Plumtree Run watershed. The benthic macroinvertebrate community at Plum-4 was sampled each of the three monitoring years, while the fish community was sampled only in Year 1.

1.1.5 Plum-5

This site is located on an unnamed tributary to Plumtree Run, primarily draining urban (98.7%) land. This site is downstream of two planned stream restoration projects and one stormwater BMP retrofit. This site will assess the ecological benefit of planned restoration in a heavily urbanized subwatershed. The benthic macroinvertebrate community at Plum-5 was sampled each of the three monitoring years, while the fish community was sampled only in Year 1.

2 Methods

2.1 Land Use and Impervious

Catchments delineating all land draining to each stream site were created in ESRI's ArcGIS 10.1.3 using topographic data from Harford County and midpoints of each site collected in the field using sub-1m accuracy Trimble GPS units paired with a tablet PC.

The resulting site catchments were then used to calculate land use and imperviousness for each site. The most recently available land use data (2010) for Harford County were obtained from Maryland Department of Planning. Impervious cover data sets included Harford County's planimetric impervious data from 2014 and the National Land Cover Dataset impervious estimate from 2011. Area of each land use category and impervious cover were calculated for each catchment and converted to a percent of the catchment.

2.2 Water Quality Sampling

Water quality conditions were measured *in situ* during the spring 2018 sampling visits at all Plumtree Run sites. Currently the MBSS does not measure *in situ* water quality at sites, but did so in the past. *In situ* water quality methods used were consistent with those in DNR, 2010. Field measured parameters include temperature, dissolved oxygen, pH, specific conductance, and turbidity. Measurements at each site were made at the upstream end of the 75-meter long site. *In situ* measurements were made before any sampling activities started to avoid sampling water disturbed by other activities. Most *in situ* parameters (i.e., temperature, pH, specific conductivity, and dissolved oxygen) were measured using a multiparameter sonde (YSI Professional Plus), while turbidity was measured with a Hach 2100 Turbidimeter. Water quality meters are regularly inspected and maintained and were calibrated immediately prior to sampling to ensure proper usage and accuracy of the readings.

2.3 Physical Habitat Assessment

Each stream site was characterized based on visual observations of physical characteristics and various habitat parameters. The Maryland Biological Stream Survey's (MBSS) Physical Habitat Index (PHI; Paul et al. 2002) was used to assess the physical habitat at the site.

To reduce individual sampler bias, assessments were completed as a team with discussion and agreement of the scoring for each parameter. In addition to the visual assessments, photographs were taken from three locations within each sampling reach (downstream end, midpoint, and upstream end) facing in the upstream and downstream direction, for a total of six (6) photographs per site.

The PHI incorporates the results of a series of habitat parameters selected for Coastal Plain, Piedmont and Highlands regions. While all parameters are rated during the field assessment, the Piedmont parameters were used to develop the PHI score for these sites because the Plumtree Run watershed is located in Maryland's Piedmont ecophysiographic region. In developing the PHI, MBSS identified eight parameters that have the most discriminatory power for the Piedmont streams. These parameters are used in calculating the PHI (Table 2). Several of the parameters have been found to be drainage area dependent and are scaled accordingly. The drainage area to each site was calculated in GIS using the GPS-collected location of each site, streams and 2-foot contour data from Harford County.

Table 2 – PHI Piedmont Parameters

Piedmont Stream Parameters	
Instream Habitat	Epifaunal Substrate
Bank Stability	Percent Shading
Remoteness	Number Woody Debris/Root wads

Each habitat parameter is given an assessment score ranging from 0-20, with the exception of shading (percentage 0-100%) and woody debris and root wads (total count). A prepared score and scaled score (0-100) are then calculated. The average of these scores yields the final PHI score. The final scores are then ranked according to the ranges shown in Table 3 and assigned corresponding narrative ratings, which allows for a score that can be compared to habitat assessments performed statewide.

Table 3 – PHI Score and Ratings

PHI Score	Narrative Rating
81.0 – 100.0	Minimally Degraded
66.0 – 80.9	Partially Degraded
51.0 – 65.9	Degraded
0.0 – 50.9	Severely Degraded

2.4 Benthic Macroinvertebrate Sampling

Benthic macroinvertebrate collection strictly followed MBSS procedures (Stranko et al. 2015). Sampling occurred during the Spring Index Period (March 1 – April 30), samples were collected from all five Plumtree Run sites on March 19, 2018. The monitoring sites consist of a 75-meter reach and benthic macroinvertebrate sampling is conducted once per year. The sampling methods utilize semi-quantitative field collections of the benthic macroinvertebrate community. The multi-habitat D-frame net approach is used to sample a range of the most productive habitat types present within the reach. Best available habitats include riffles, stable woody debris, root wads, root mats, leaf packs, aquatic macrophytes, and undercut banks. In this sampling approach, a total of twenty kicks or jabs (each approximately one square foot) are distributed proportionally among all best available habitats within the stream site and combined into a single composite sample and preserved in 95 percent ethanol. The composite sample contains material collected from approximately 20 square feet of habitat.

MBSS specifies that a minimum of 5% (1 in 20) of sites are selected for a duplicate sample (Stranko et al. 2015). Because the total number of samples in this project (5) is well below 20, Plumtree Run samples were pooled with other County monitoring project samples from Foster Branch (5) to meet the field sampling QC objective (1 in 10, or 10.0%). The randomly selected QC site for 2018 was taken at Plum-3.

2.4.1 Benthic Macroinvertebrate Sample Processing and Laboratory Identification

Benthic macroinvertebrate samples were processed and subsampled according to methods described in the MBSS Laboratory Methods for Benthic Macroinvertebrate Processing and Taxonomy (Boward and Friedman 2011). Subsampling was conducted to standardize the sample size and reduce variation caused by samples of different size. In this method, the sample was spread evenly across a numbered, gridded tray (100 total grids), and a grid was picked at random and picked clean of organisms. If the organism count was 100 or more, then the subsampling was complete. If the organism count was less than 100, then another grid was selected at random and picked clean of organisms. This repeated until the organism count reached 100 to 120 organisms. The 100 (plus 20 percent) organism target is used to allow for specimens that are missing parts or are not mature enough for proper identification, are terrestrial, or meiofauna. Identification of the subsampled specimens was conducted by Environmental Services and Consulting, Inc. Taxa were identified to the genus level for most organisms. Groups including Oligochaeta and Nematomorpha were identified to the family level while Nematomorpha was left at phylum. Individuals of early instars or those that were damaged were identified to the lowest possible level, which could be phylum or order, but in most cases was family. Chironomidae could be further subsampled depending on the number of individuals in the sample and the numbers in each subfamily or tribe. Most taxa were identified using a stereoscope. Temporary slide mounts viewed with a compound microscope were used to identify Oligochaeta to family and for Chironomid sorting to subfamily and tribe. Permanent slide mounts were then used for Chironomid genus level identification. Results were logged on a bench sheet and entered into a spreadsheet for analysis.

Benthic macroinvertebrate lab quality control procedures followed those used by the MBSS (Boward and Friedman 2011). Because the total number of samples in this project (5) is well below 20, Plumtree Run samples were pooled with samples from Foster Branch (5) to meet the laboratory QC objective (1 in 10, or 10.0%). The lab QC samples were selected at random from either Foster Branch or Plumtree Run samples. One (1) sample was randomly selected from Plumtree Run for QC re-identification by an independent lab.

2.4.2 Benthic Macroinvertebrate Data Analysis

Benthic macroinvertebrate data were analyzed by KCI using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. The metrics selected fall into five major groups including taxa richness, composition measures, tolerance to perturbation, trophic classification, and habit measures. Raw values from each metric were given a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled IBI score from 1.0 to 5.0, and a corresponding narrative biological condition rating was applied.

Three sets of metric calculations have been developed for Maryland streams based on broad eco-physiographic regions. These include the Coastal Plain, Piedmont and combined Highlands. The study area is located in the Piedmont region therefore the following metrics (Table 4) and IBI scoring (Table 5) were used for the analysis.

Table 4 – Benthic Macroinvertebrate Metric Scoring for the Piedmont BIBI

Metric	Score		
	5	3	1
Total Number of Taxa	≥ 25	15 – 24	< 15
Number of EPT Taxa	≥ 11	5 – 10	< 5
Number of Ephemeroptera Taxa	≥ 4	2 – 3	< 2
% Intolerant to Urban	≥ 51	12 – 50	< 12
% Chironomidae	≤ 24	24 – 63	> 63
% Clingers	≥ 74	31 – 73	< 31

*Adjusted for catchment size

Table 5 – BIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

2.5 Fish Sampling

The fish community at each of the five Plumtree Run sites was sampled during the Summer Index Period, June 1 through September 30, according to methods described in *Maryland Biological Stream Survey: Round Four Field Sampling Manual* (Stranko et al. 2015). In general, the approach uses two-pass electrofishing of the entire 75-meter study reach. Block nets were placed at the upstream and downstream ends of the reach, as well as at tributaries or outfall channels, to obstruct fish movement into or out of the study reach. Two passes were completed along the reach to ensure the segment was adequately sampled. The time in seconds for each pass was recorded and the level of effort for each pass was similar. Captured fish were identified to species and enumerated following MBSS protocols (Stranko et al. 2015). A total fish biomass for each electrofishing pass was measured. Unusual anomalies such as fin erosion, tumors, etc. were recorded. Photographic vouchers were taken in lieu of voucher specimens.

2.5.1 Fish Data Analysis

Fish data for Plumtree Run sites were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The IBI approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. Raw values from each metric were assigned a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled FIBI score, ranging from 1.0 to 5.0, and a corresponding narrative rating of 'Good', 'Fair', 'Poor' or 'Very Poor' was applied, again in accordance with standard practice.

Four sets of FIBI metric calculations have been developed for Maryland streams. These include the Coastal Plain, Eastern Piedmont, and warmwater and coldwater Highlands. Plumtree Run is located in the Eastern Piedmont region, therefore, the following metrics listed in Table 6 were used for the FIBI scoring (Table 7) and analysis.

Table 6 – Fish Metric Scoring for the Piedmont FIBI

Metric	Score		
	5	3	1
Abundance per Square Meter	≥ 1.25	0.25 – 1.24	< 0.25
Number of Benthic species *	≥ 0.26	0.09 – 0.25	< 0.09
% Tolerant	≤ 45	46 – 68	> 68
% Generalist, Omnivores, Invertivores	≤ 80	81 – 99	100
Biomass per Square Meter	≥ 8.6	4.0 – 8.5	< 4.0
% Lithophilic Spawners	≥ 61	32 – 60	< 32

*Adjusted for catchment size

Table 7 – FIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

2.6 Herpetofauna Survey

Herpetofauna (i.e., reptiles and amphibians) were surveyed at each of the five Plumtree Run sites using methods following MBSS protocols (Stranko et al. 2015); 1) incidental collection, and 2) a search within all suitable stream salamander habitats within the 75-meter site. All collected individuals were identified to species level and released. Photographic vouchers were collected if a specimen could not be positively identified in the field.

Herpetofauna data collection occurs primarily to assist MBSS with supplementing their inventory of biodiversity in Maryland's streams. Currently, MBSS has not developed any indexes of biotic integrity for herpetofauna, and therefore, they were not used to evaluate the biological integrity of sampling sites throughout this study. Rather, the data are provided to help document existing conditions.

2.7 Freshwater Mussel Survey

A survey of freshwater mussels was conducted at each site using MBSS protocols (Stranko et al. 2015). Any live individuals encountered were identified, photographed, and then returned back to the stream as closely as possible to where they were collected. Any dead shells were retained as voucher specimens.

2.8 Crayfish Survey

Crayfish were surveyed for at each site using MBSS protocols (Stranko et al. 2015). All crayfish observed while electrofishing were captured and retained until the end of each electrofishing pass. Captured crayfish were identified to species and counted before release back into the stream outside of the 75-meter sampling reach. Any crayfish encountered outside of the electrofishing effort were identified and noted on the datasheet as an incidental observation. Any crayfish burrows observed in and around the sampling site were excavated and an attempt made to capture the burrowing crayfish.

2.9 Invasive Plant Survey

A survey of invasive plants was performed at each site during the Summer Index Period following MBSS protocols (Stranko et al. 2015). The common name and relative abundance of invasive plants (i.e., present or extensive) within view of the study reach and within the 5-meter riparian vegetative zone parallel the stream channel were recorded.

Invasive plant data collection occurs to assist MBSS with supplementing their inventory of biodiversity. The data are provided to help document existing conditions at each site.

2.10 Quality Assurance and Quality Control

All work was conducted with thorough quality assurance and quality control. Biological assessment methods have been designed to be consistent and comparable with the methods used by MBSS (Stranko et al. 2015). Field crews receive yearly training in MBSS protocols and certification by DNR to perform benthic macroinvertebrate and fish sampling procedures. The Certified Fish Sampling Field Crew Leader and Fish Taxonomist for this project was Andy Becker. All field forms are checked and signed by the Crew Leader before leaving the site. Digital data entry is also checked for accuracy. Field equipment are checked regularly and calibrated as necessary prior to use. Calculation of metric scores and IBIs are completed using KCI's controlled and verified spreadsheet and each site undergoes a documented quality control check.

3 Results and Discussion

Biological monitoring and water quality sampling were conducted to assess the conditions in the Plumtree Run watershed. Presented below are the summary results for each monitoring component.

3.1 Land Use

The results of the land use analysis and impervious for Harford County and NLCD are presented below in Table 8.

Table 8 – Land Use and Imperviousness of Plumtree Run Sites

Site	Urban	Agriculture	Forest	Other	Harford Co Impervious	NLCD Impervious
Plum-1	87.9%	7.2%	4.8%	0.0%	36.16%	15.64%
Plum-2	90.4%	5.8%	3.8%	0.0%	39.87%	18.29%
Plum-3	93.5%	6.5%	0.0%	0.0%	50.44%	27.98%
Plum-4	71.3%	2.4%	26.3%	0.0%	34.48%	17.01%
Plum-5	98.7%	0.0%	1.3%	0.0%	30.99%	5.47%

3.2 Water Quality

Water quality measurements were collected during the Summer Index Period sampling visit during all three years at each of the five Plumtree Run sites. Table 9 presents the results of the *in situ* water quality measurements.

Table 9 – In Situ Water Quality Measurement Results

Site	Season	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductance (µS/cm)	Turbidity (NTU)
Plum-1	Summer 2015	15.1	9.92	7.52	596.7	0.89
Plum-1	Summer 2016	19.4	9.01	7.41	332.2	2.23
Plum-1	Summer 2017	21.0	8.75	7.82	436.9	7.89
Plum-2	Summer 2015	17.6	9.94	7.22	672.0	4.95
Plum-2	Summer 2016	21.7	7.41	6.98	357.9	3.67
Plum-2	Summer 2017	23.2	7.14	8.98	482.8	8.93
Plum-3	Summer 2015	16.5	8.54	7.18	887.0	1.72
Plum-3	Summer 2016	22.6	8.36	6.92	726.0	1.30
Plum-3	Summer 2017	22.0	6.41	7.22	589.0	5.08
Plum-4	Summer 2015	15.4	7.01	6.81	384.2	1.13
Plum-5	Summer 2015	17.8	7.22	7.12	433.9	1.40

Shaded cells indicate values outside of the acceptable water quality criteria range or published values

MDE has established acceptable water quality standards for each designated Stream Use Classification, which are listed in the *Code of Maryland Regulations (COMAR) 26.08.02.03-.03 - Water Quality*. Plumtree Run is covered in *COMAR* in Sub-Basin 02-13-07: Bush River Area as Use IV-P waters. Specific designated uses for Use IV-P streams include public water supply, supporting adult trout for put-and-take fishing, growth and propagation of fish and aquatic life, water supply for industrial and agricultural use, water contact sports, fishing, and leisure activities involving direct water contact.

The acceptable criteria for Use IV-P waters are as follows:

- pH - 6.5 to 8.5
- DO - may not be less than 5 mg/l at any time
- Turbidity - maximum of 150 Nephelometric Turbidity Units (NTU's) and maximum monthly average of 50 NTU
- Temperature - maximum of 75°F (23.9°C) or ambient temperature of the surface water, whichever is greater

In situ water quality measurements for temperature, dissolved oxygen, and turbidity were within COMAR standards for Use IV-P streams. At Plum-2 during Year 3/Summer of 2017 the pH was 8.98, exceeding the COMAR criteria. All other pH values fell within the criteria. Although MDE does not have a water quality standard for specific conductivity, Morgan and others (Morgan et al, 2007; Morgan et al, 2012) have reported critical values for specific conductance in Maryland streams, above which there is a potential for detrimental effects on the stream biological communities. For the benthic macroinvertebrate community that critical value is 247 µS/cm, and for the fish community it is 171 µS/cm. Each of the five Plumtree Run stream sites had specific conductivity values far exceeding the threshold for both benthic macroinvertebrate and fish community impairments for all water quality sampling events. Conductivity levels in this watershed are likely influenced by runoff from impervious surfaces (i.e., roads, sidewalks, parking lots, roof tops). Increased stream inorganic ion concentrations (i.e., conductivity) in urban systems typically results from paved surface de-icing, accumulations in storm-water management facilities (Casey et al. 2013), runoff over impervious surfaces, passage through pipes, and exposure to other infrastructure (Cushman 2006). While elevated conductivity may not directly affect stream biota, its constituents (e.g., chloride, metals, and nutrients) may be present at levels that can cause biological impairment.

3.3 Physical Habitat Assessment

The summary results of the PHI habitat assessments for Year 1 and Year 2 and Year 3 are presented in Table 10. All Plumtree Run sites have compromised physical habitat, with PHI ratings of 'Degraded' for all sites in Year 1 and all sites in Year 2 except Plum-1. Plum-1 had the best habitat scores of the five sites with a 'Partially Degraded' in Year 2. Year 3 had the same results as Year 2 with Plum-1 receiving a rating of 'Partially Degraded' while the other sites both received ratings of 'Degraded'. The relatively low habitat scores are likely due to urbanization effects on streams. Complete physical habitat data for each site are included in Appendix A.

Table 10 – RBP and PHI Habitat Assessment Results

Site	Season	PHI Score	PHI Narrative Rating
Plum-1	Summer 2015	64.6	Degraded
Plum-1	Summer 2016	71.2	Partially Degraded
Plum-1	Summer 2017	66.4	Partially Degraded
Plum-2	Summer 2015	54.0	Degraded
Plum-2	Summer 2016	58.5	Degraded
Plum-2	Summer 2017	58.2	Degraded
Plum-3	Summer 2015	59.0	Degraded
Plum-3	Summer 2016	64.1	Degraded
Plum-3	Summer 2017	60.4	Degraded
Plum-4	Summer 2015	59.5	Degraded
Plum-5	Summer 2015	54.2	Degraded

3.4 Benthic Macroinvertebrate Community

The results of Year 3 benthic macroinvertebrate community assessments are presented in Table 11. Complete benthic macroinvertebrate data for each site are included in Appendix B.

Table 11 – Benthic Index of Biotic Integrity (BIBI) Summary Data – Year 3

Metric	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5	Plum-3 QC
Metric Values						
Total Number of Taxa	15	19	17	12	29	17
Number of EPT Taxa	2	4	4	2	2	3
Number of Ephemeroptera Taxa	0	0	0	0	0	0
% Intolerant to Urban	0.92	0.92	0.00	5.65	0.73	0.00
% Chironomidae	93	82.57	83.74	92.74	77.37	83.94
% Clingers	0.92	22.02	33.33	12.90	10.95	27.74
Metric Scores						
Total Number of Taxa	3	3	3	1	5	3
Number of EPT Taxa	1	1	1	1	1	1

Metric	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5	Plum-3 QC
Number of Ephemeroptera Taxa	1	1	1	1	1	1
% Intolerant to Urban	1	1	1	1	1	1
% Chironomidae	1	1	1	1	1	1
% Clingers	1	1	3	1	1	1
BIBI Score	***1.33***	***1.33***	***1.67***	***1.00***	***1.67***	***1.33***
Narrative Rating	***Very Poor***	***Very Poor***	***Very Poor***	***Very Poor***	***Very Poor***	***Very Poor***

For Year 3 benthic macroinvertebrate sampling, all five Plumtree Run sites had BIBI ratings in the 'Very Poor' category, with Plum-4 scored 1.00, the lowest score possible.

At the Plumtree Run sites BIBI scores ranged from 1.00 to 1.67. The individual metrics scored consistently low across all sites, with only Plum-5 'Total Number of Taxa' scoring a '5', the highest score possible. Four metrics, Number of EPT Taxa, Number of Ephemeroptera Taxa, Percent Intolerant to Urban, and Percent Chironomidae scored consistently low across all five sites with each site scoring the lowest possible '1' for these three metrics. Minor differences in the other two metrics (Total Number of Taxa, and Percent Clingers) accounted for the variation in BIBI scores for Plum-1, Plum-2, Plum-3, and Plum-4. These low BIBI scores are possibly due to poor habitat and water quality. All sites had measured specific conductivity values greater than the published impairment threshold for benthic macroinvertebrates.

The QC sample from Plum-3 scored similarly to the non-QC sample, in the 'Very Poor' category. The QC sample had smaller Percent Clingers, driving the BIBI lower than the non-QC sample. This is most likely due to the naturally-occurring patchy distribution of benthic macroinvertebrates.

A comparison of BIBI scores across the three years of monitoring is presented in Table 12 and Figure 2. Three of the five Plumtree Run sites had BIBI scores that were higher in Year 3 than in Year 2 (Plum-1, Plum-2 and Plum-3), while Plum-5 remained the same between years and Plum-4 decreased between Years 2 and 3. Site Plum-4 had the largest BIBI score difference (-1.00), scoring a 2.00 in Year 2 and a 1.00 in Year 3. Sites Plum-1, Plum-2, and Plum-3 had the smallest BIBI score differences (-0.33), and Plum-5 had no change between years.

Table 12 – BIBI Scores and Narrative Rating for all Years

Site	Year	BIBI Score	Narrative Rating
Plum-1	1 (Spring 2016)	2.67	Poor
Plum-1	2 (Spring 2017)	1.00	Very Poor
Plum-1	3 (Spring 2018)	1.33	Very Poor
Plum-2	1 (Spring 2016)	2.00	Poor
Plum-2	2 (Spring 2017)	1.00	Very Poor
Plum-2	3 (Spring 2018)	1.33	Very Poor
Plum-3	1 (Spring 2016)	2.00	Poor
Plum-3	2 (Spring 2017)	1.33	Very Poor
Plum-3	3 (Spring 2018)	1.67	Very Poor
Plum-4	1 (Spring 2016)	2.33	Poor
Plum-4	2 (Spring 2017)	2.00	Poor
Plum-4	3 (Spring 2018)	1.00	Very Poor
Plum-5	1 (Spring 2016)	2.00	Poor
Plum-5	2 (Spring 2017)	1.67	Very Poor
Plum-5	3 (Spring 2018)	1.67	Very Poor

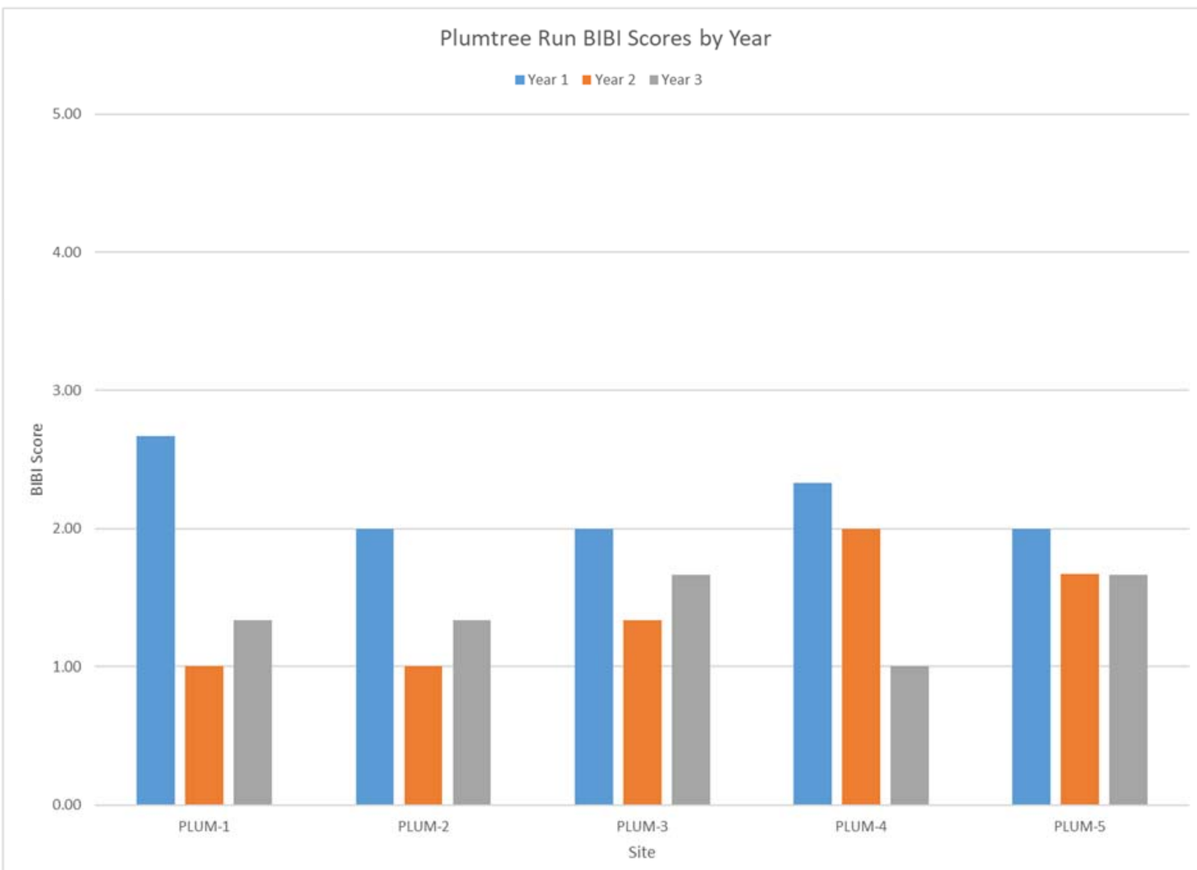

Figure 2 – BIBI Scores by Year

3.5 Fish Community

The results of the Year 3 fish community assessments are presented in Table 13 and a list of species collected over all three sampling years at each site can be found in Table 14. Complete fish community data for each site are included in Appendix C.

The Plumtree Run sites had FIBI ratings ranging from 'Fair' to 'Good'. Sites Plum-4 and Plum-5 were only sampled in Year 1 as per the Plumtree Run Monitoring Plan.

Table 13 – Fish Index of Biotic Integrity (FIBI) Summary Data – Year 3

Metric	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
Metric Values					
Abundance per Square Meter	1.41	5.02	3.57	n/a	n/a
Adjusted Number of Benthic Species	0.62	0.65	0.84	n/a	n/a
% Tolerant	50.00%	75.21%	71.42%	n/a	n/a
% Generalist, Omnivores, Invertivores	63.48%	85.27%	84.52%	n/a	n/a
Biomass per Square Meter	3.21	11.47	8.30	n/a	n/a
% Lithophilic Spawners	63.48%	28.98%	53.12%	n/a	n/a
Metric Scores					
Abundance per Square Meter	5	5	5	n/a	n/a
Adjusted Number of Benthic Species	5	5	5	n/a	n/a
% Tolerant	3	1	1	n/a	n/a
% Generalist, Omnivores, Invertivores	5	3	3	n/a	n/a
Biomass per Square Meter	1	5	3	n/a	n/a
% Lithophilic Spawners	5	1	3	n/a	n/a
FIBI Score	***4.00***	***3.33***	***3.33***	***n/a***	***n/a***
Narrative Rating	***Good***	***Fair***	***Fair***	***n/a***	***n/a***

Table 14 – Cumulative List of Fish Species Collected at Plumtree Run Sites

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
White Sucker	*Catostomus commersonii*	X	X	X		
Bluntnose Minnow	*Pimephales notatus*	X	X	X		
Fathead Minnow	*Pimephales promelas*	X	X	X		
Cutlip Minnow	*Exoglossum maxillingua*		X			
Satinfin Shiner	*Cyprinella analostana*		X			
Common Shiner	*Luxilus cornutus*	X	X			
Rosyside Dace	*Clinostomus funduloides*	X	X	X		
Creek Chub	*Semotilus atromaculatus*	X	X	X	X	X
Fallfish	*Semotilus corporalis*	X	X			
Blacknose Dace	*Rhinichthys atratulus*	X	X	X	X	X
Longnose Dace	*Rhinichthys cataractae*	X	X	X	X	X
Eastern Mosquitofish	*Gambusia holbrooki*		X			

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
Blue Ridge Sculpin	*Cottus caeruleomentum*	X	X	X		X
Tessellated Darter	*Etheostoma olmstedi*		X			
Redbreast Sunfish	*Lepomis auritus*	X	X	X		
Bluegill	*Lepomis macrochirus*			X		
Pumplkinseed	*Lepomis gibbosus*		X			
Green Sunfish	*Lepomis cyanellus*			X		
Hybrid Sunfish	*Lepomis sp.*		X			

Site Plum-1 had the highest FIBI score, 4.00 which rated 'Good'. Sites Plum-2 and Plum-3 both scored a 3.33 rating 'Fair'. Eleven species of fish have been collected at Plum-1 and Plum-3, and 17 species collected at Plum-2 (the restored site) which had the highest diversity of the five sites. Metrics for Abundance per square meter, and Adjusted Number of Benthic Species were consistent between the three sites. Biomass per Square Meter varied the most between the sites, with Plum-2 scoring a '5', Plum-3 scoring a '3', and Plum-1 scoring a '1'. Percent Lithophilic Spawners also had large variation between the sites with Plum-1 scoring a '5', Plum-3 scoring a '3', and Plum-2 scoring a '1'. Minor differences in the other three metrics between sites accounted for the minor variability in FIBI scores between sites

A comparison of FIBI scores across the three years of monitoring is presented in Table 15 and Figure 3. Overall, FIBI scores at the three Plumtree Run sites monitoring in the three years varied slightly. Plum-3 scored a 3.33 all three years, Plum-1 had a slightly lower FIBI score (-0.33) in Year 2, but then increased to 4.00 in Year 3 and Plum-2 had a slightly higher FIBI score (0.33) in Year 2, but then decreased in FIBI score (-0.67) in Year 3.

Table 15 – FIBI Scores and Narrative Rating Across Years

Site	Year	FIBI Score	Narrative Rating
Plum-1	1 (Summer 2015)	3.67	Fair
Plum-1	2 (Summer 2016)	3.33	Fair
Plum-1	3 (Summer 2017)	4.00	Good
Plum-2	1 (Summer 2015)	3.67	Fair
Plum-2	2 (Summer 2016)	4.00	Good
Plum-2	3 (Summer 2017)	3.33	Fair
Plum-3	1 (Summer 2015)	3.33	Fair
Plum-3	2 (Summer 2016)	3.33	Fair
Plum-3	3 (Summer 2017)	3.33	Fair
Plum-4	1 (Summer 2015)	2.67	Poor
Plum-5	1 (Summer 2015)	2.67	Poor

3.1 Herpetofauna

At least two reptile or amphibian species were collected at each of the sites (Table 16). Plum-2 had the highest diversity with five species present at the site. The most widely distributed species was Northern Two-lined Salamander, which was present at each of the five Plumtree Run sites. Numbers of stream salamander individuals were low at all sites where they were observed; one or two Northern Two-lined Salamander individuals were observed at most sites, Plum-5 had the greatest stream salamander abundance with four Northern Two-lined Salamanders and one Northern Dusky observed during summer of 2015.

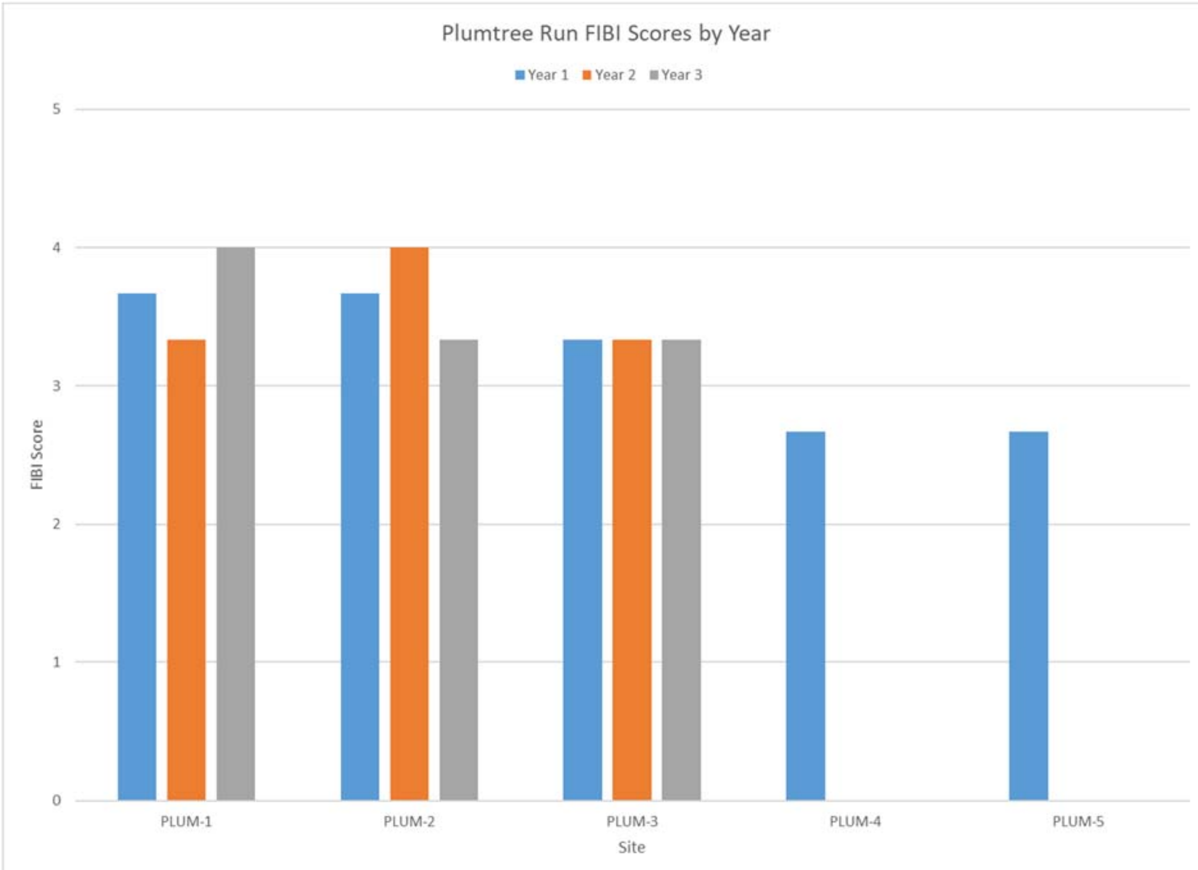

Figure 3 – FIBI Scores by Year

Table 16 – Cumulative Herpetofauna Presence at Plumtree Run Sites

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
American Toad	*Anaxyrus americanus*	X		X		
Northern Green Frog	*Lithobates clamitans melanota*	X	X	X	X	
Northern Spring Peeper	*Pseudacris crucifer*		X			
Northern Watersnake	*Nerodia sipedon sipedon*		X			
Queen Snake	*Regina septemvittata*		X			
Stream Salamanders						
Northern Dusky Salamander	*Desmognathus fuscus*					X
Northern Two-lined Salamander	*Eurycea bislineata*	X	X	X	X	X

The low density of stream salamanders at all sites is likely due to a combination of habitat degradation and water quality impairment. There was very little suitable stream salamander habitat present at Plum-2 during all three years for the field crew to search. Stream salamanders generally prefer large cover objects over loose cobble and gravel, creating a moist microclimate and many interstices for shelter and foraging. The restoration reach (Plum-2) contained several areas of armored banks and rock structures in the stream. Water quality may be influencing the distribution of stream salamanders in the Plumtree Run watershed. Measured specific conductivity was high at all five sites, ranging from 332 to 887 µS/cm. Stream salamanders breathe through their skins, and because of their highly permeable skin are particularly sensitive to water quality impairments. The high conductivity values suggest that salamanders would experience osmotic difficulties in these conditions.

3.2 Freshwater Mussels

No freshwater mussels were observed at any Plumtree Run site in Year 1, Year 2, nor Year 3. The lack of freshwater mussels at these sites is likely due to a combination of habitat degradation and water quality impairment. Freshwater mussels are relatively sessile organisms which live partially embedded within the stream substrates. The flashy hydrology characteristic of urban streams like Plumtree Run create habitat conditions unsuitable for freshwater mussels. Also, it is likely that water quality conditions in urban streams are outside the range of tolerance of these sensitive organisms.

3.3 Crayfish

Crayfish were observed at each of the five Plumtree Run sites. *Orconectes virilis*, a non-native species, was the only crayfish species observed at these sites. At Plum-1, Plum-2, and Plum-3 *O. virilis* was observed during electrofishing in Year 1, Year 2, and Year 3 sampling efforts. Crayfish burrows were not observed at any of the Plumtree Run sites. The lack of native crayfish is most likely due to competition with non-native crayfish. In the Patapsco River watershed, *Orconectes virilis* has displaced the native *Orconectes limosus* from the entire watershed (Kilian et al. 2010). It is likely that a similar species displacement has occurred in the Winters Run watershed. Water quality conditions may also be impacting crayfish, but currently the water quality requirements for crayfish in Maryland are poorly understood.

3.4 Invasive Plant Species

Invasive plant species were present at each of the five Plumtree Run sites. Table 17 presents all invasive species found at each monitoring site across all sampling visits. Plum-2 has the most invasive plant species with eleven, and Plum-4 had the least with four. Japanese stiltgrass and Mulitflora rose were the most widely distributed invasive plant, each found at all five sites.

Table 17 – Cumulative Invasive Plant Species Presence at Plumtree Run Sites

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
Garlic Mustard	*Allaria petiolata*		X			
Common ragweed	*Ambrosia artemisiifolia*		X			
Japanese barberry	*Berberis thunbergii*	X			X	
Oriental bittersweet	*Celastrus orbiculatus*	X		X		X
Fireweed	*Chamerion angustifolium*			X		
Autumn Clematis	*Clematis terniflora*		X			
Ground ivy	*Glechoma hederacea*		X			
English ivy	*Hedera helix*	X	X			
Chinese Lespedeza	*Lespedeza cuneata*		X			
Japanese honeysuckle	*Lonicera japonica*			X		X
Japanese stiltgrass	*Microstegium vimineum*	X	X	X	X	X
Mile-a-minute	*Persicaria perfoilata*		X	X		X
Multiflora rose	*Rosa multiflora*	X	X	X	X	X
Wineberry	*Rubus phoenicolasius*		X	X	X	
Vinca vine	*Vinca sp.*		X			

4 Analysis and Discussion

4.1 Annual Data

Data from all three years of the Plumtree Run monitoring effort were compiled and analyzed to detect changes in condition over the three years of monitoring. Mean annual BIBI scores fluctuated during the three years of monitoring but the differences between years were not significant (Table 18, Figure 4). Mean annual FIBI scores for Plumtree Run sites were generally higher and varied more than BIBI scores (Table 18, Figure 5). Differences in mean FIBI scores across years was not significant.

Table 18 – Mean BIBI and FIBI Scores by Year for Plumtree Run Sites

	Year 1	Year2	Year 3
BIBI			
Mean	2.20	1.40	1.40
SD	0.299	0.435	0.279
FIBI			
Mean	3.20	3.55	3.56
SD	0.505	0.387	0.385

4.1 Comparison with MBSS Data

Data from the MBSS were obtained from MD DNR. Since Plumtree Run is in the Piedmont strata used by MBSS, we selected only MBSS sites from the Piedmont for a comparative analysis. Impervious data from the 2011 NLCD was used for Plumtree Run sites to remain consistent with impervious data used by MBSS. Two of the Plumtree Run sites; Plum-4, and Plum-5; do not fall on the 1:100,000 scale stream file used by MBSS and are possibly smaller in watershed size than sites normally sampled by MBSS.

MBSS frequently cites higher urban land use, and impervious surfaces especially, result in lower BIBI in streams across Maryland. To relate the results from Plumtree Run to ecological condition and possible stressors for other streams in Maryland, we compared Plumtree Run results with MBSS Piedmont sites from 1995-2017.

Plumtree Run BIBI scores were plotted with MBSS results against percent urban land use (Figure 6) and percent imperviousness (Figure 7). A regression analysis was performed on these same variables. Plumtree Run BIBI scores showed a weak, negative, non-significant relationship with percent urban land use (R^2=0.003, p=0.85). The low R2 value is not surprising, all five of the Plumtree Run sites have high amounts of urban landuse, so the variance in the BIBI scores is influenced more by other variables. There was also a weak, negative, non-significant relationship with percent imperviousness (R^2=0.008, p=0.75). When plotted with the distribution of MBSS Piedmont sites, we see that Plumtree Run sites generally plot in the lower, more disturbed portion of the MBSS distribution for percent urban (Figure 6) and for percent imperviousness (Figure 7). The Plumtree Run sites fall in line with MBSS sites with lowest BIBI scores and highest percent urban; these sites are among the most urbanized of sites with

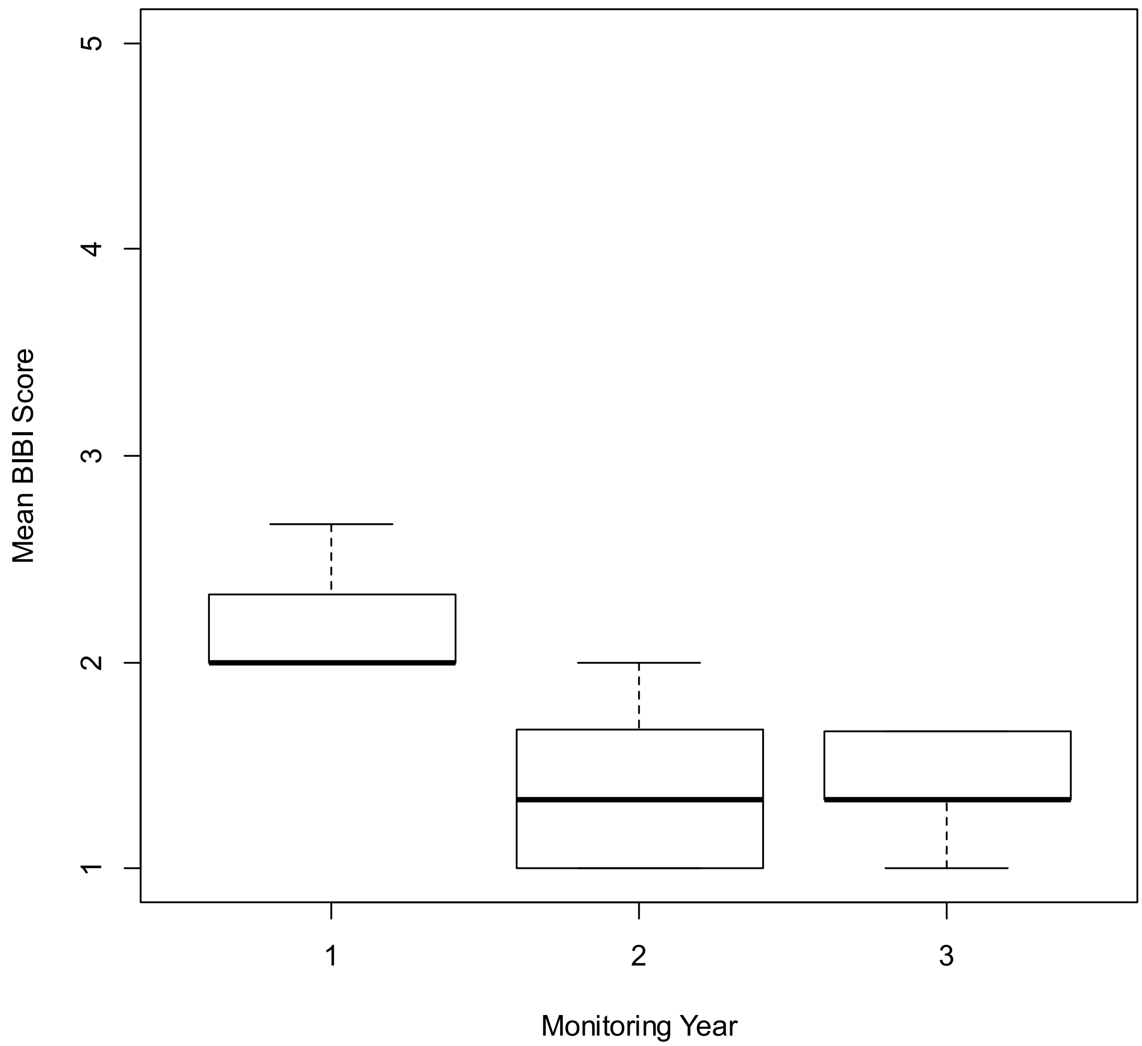

Figure 4 - Boxplots for Annual BIBI Scores for Plumtree Run Sites

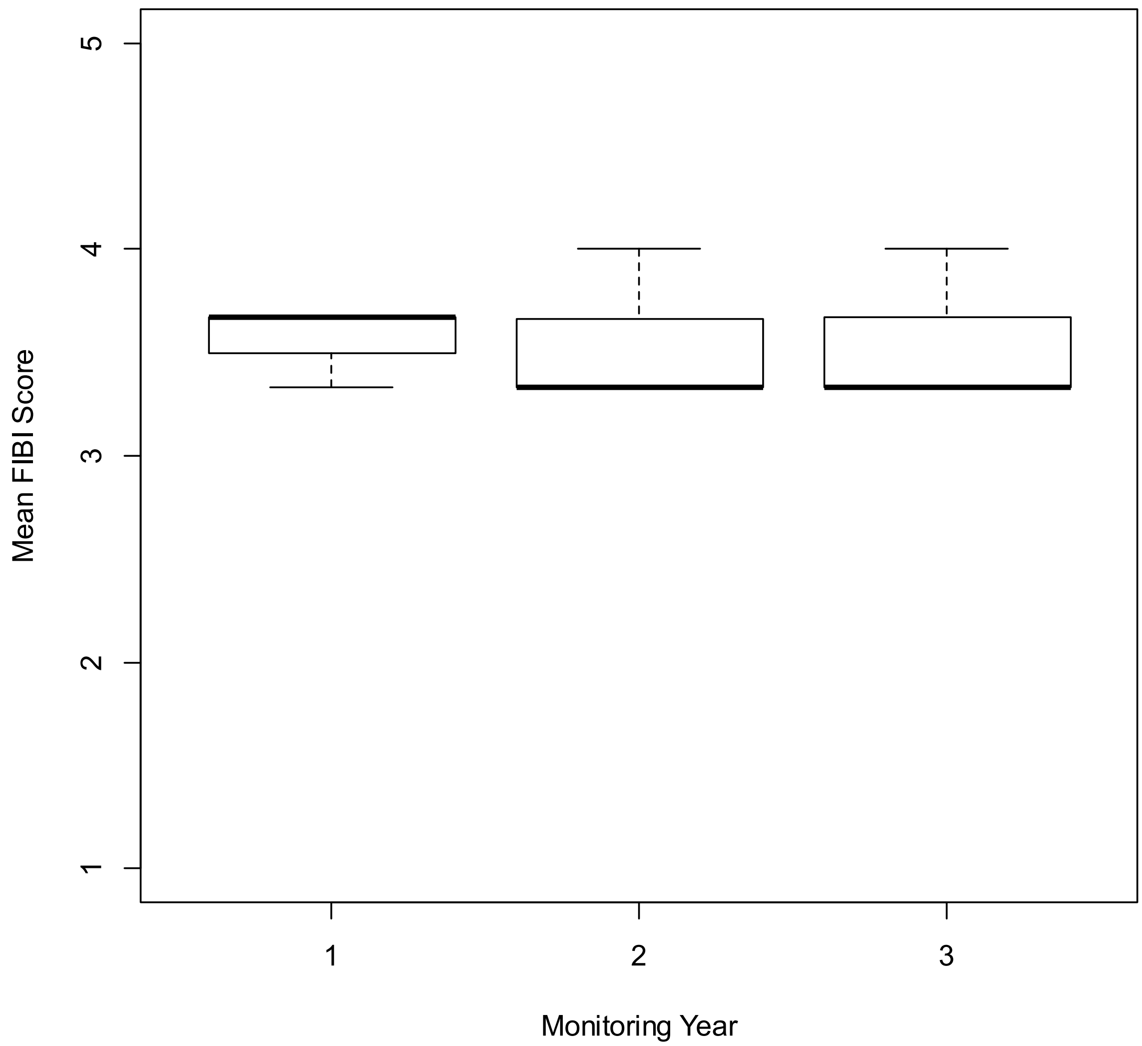

Figure 5 – Boxplots for Annual FIBI Scores for Plumtree Run Sites

the lowest BIBI scores of sites in the Piedmont. For percent imperviousness the Plumtree Run sites are generally clustered among the MBSS Piedmont sites with lower BIBI scores, but not among the sites with the highest amount of imperviousness. One possible explanation for this is that the sites in Plumtree Run have benthic macroinvertebrate communities that may be more sensitive to the effects of urbanization than the majority of streams in Maryland's Piedmont.

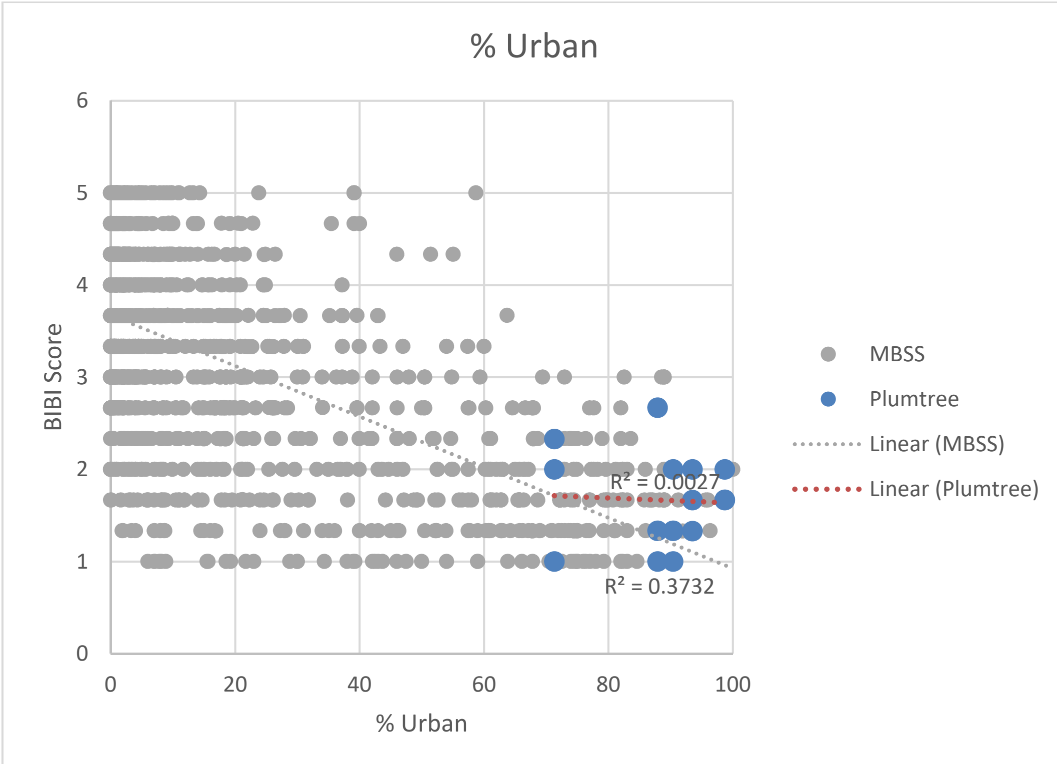

Figure 6 - BIBI score vs percent urban land use at Plumtree Run and MBSS (1995-2017) sampling sites

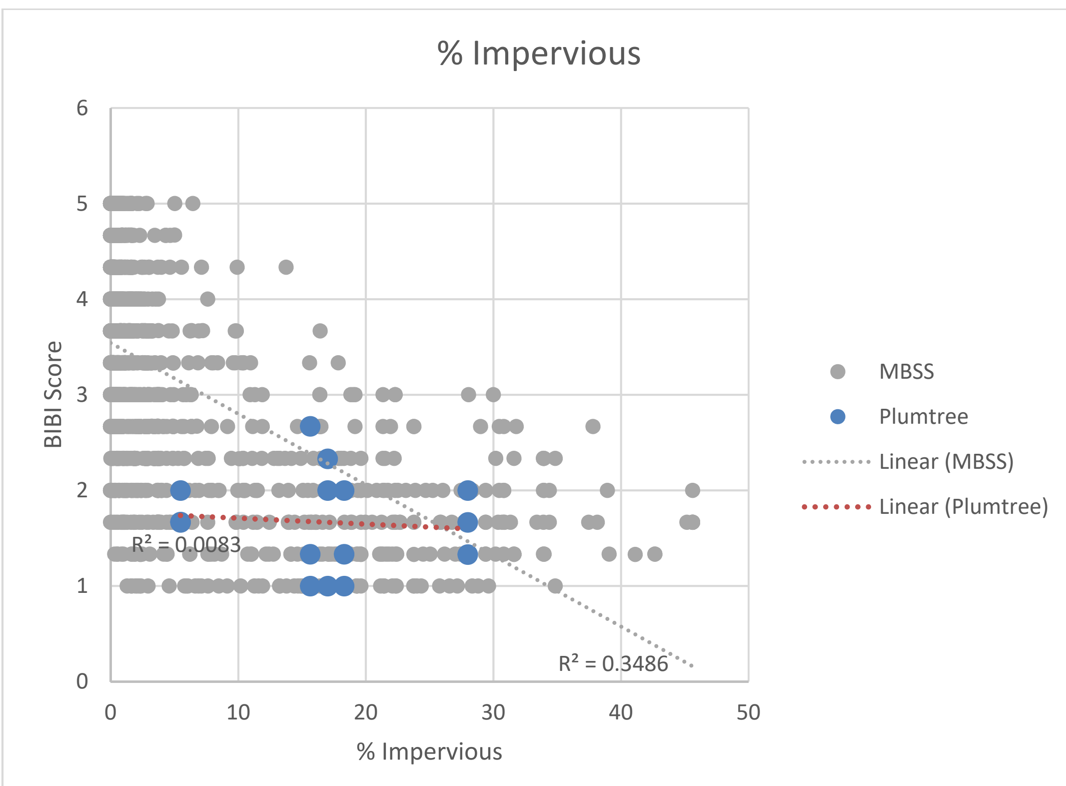

Figure 7 - BIBI score vs percent impervious land cover at Plumtree Run and MBSS (1995-2017) sampling sites

Plumtree Run FIBI scores were also plotted with MBSS data against percent urban land use (Figure 8) and percent imperviousness (Figure 9). A regression analysis was performed on these variables. Plumtree Run FIBI scores showed a positive, non-significant relationship with percent urban land use (R^2=0.03, p=0.62). There was also a positive, but non-significant relationship with percent imperviousness (R^2=0.04, p=0.54). This is contrary to patterns seen in the larger state-wide MBSS dataset and our understanding of stream ecological response to urbanization. These regressions are non-significant and should not be considered a possible pattern in fish community response to urbanization peculiar to the Plumtree Run watershed. When plotted with the distribution of MBSS Piedmont sites, we see that Plumtree Run sites generally plot as sites with better FIBI scores than MBSS Piedmont sites with similar percent urban (Figure 8) or percent imperviousness (Figure 9). This may reflect fish communities at Plumtree Run sites that are less sensitive to the effects of urbanization than other Piedmont streams. Another potential explanation could be that the smaller two Plumtree Run sites not on the MBSS stream network are approaching the stream size limit for fish occupancy. A development of a species-area curve from MBSS data would help answer this question.

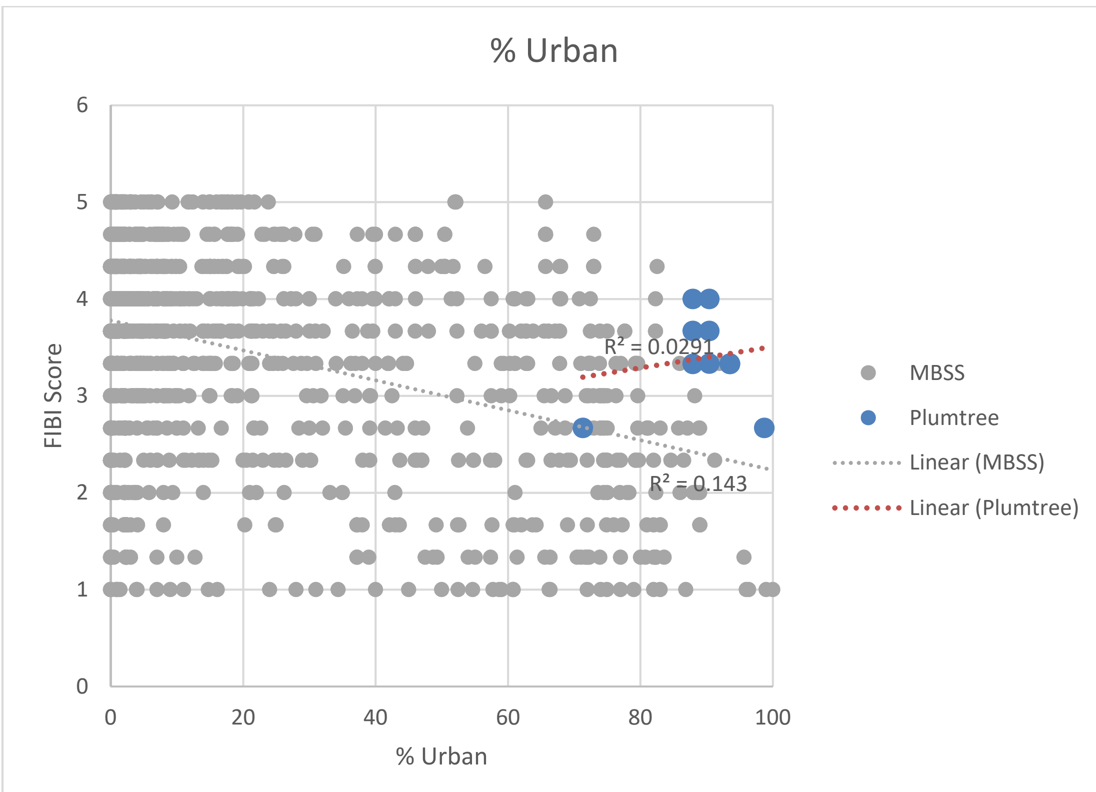

Figure 8 - FIBI score vs percent urban land use at Plumtree Run and MBSS (1995-2017) sampling sites

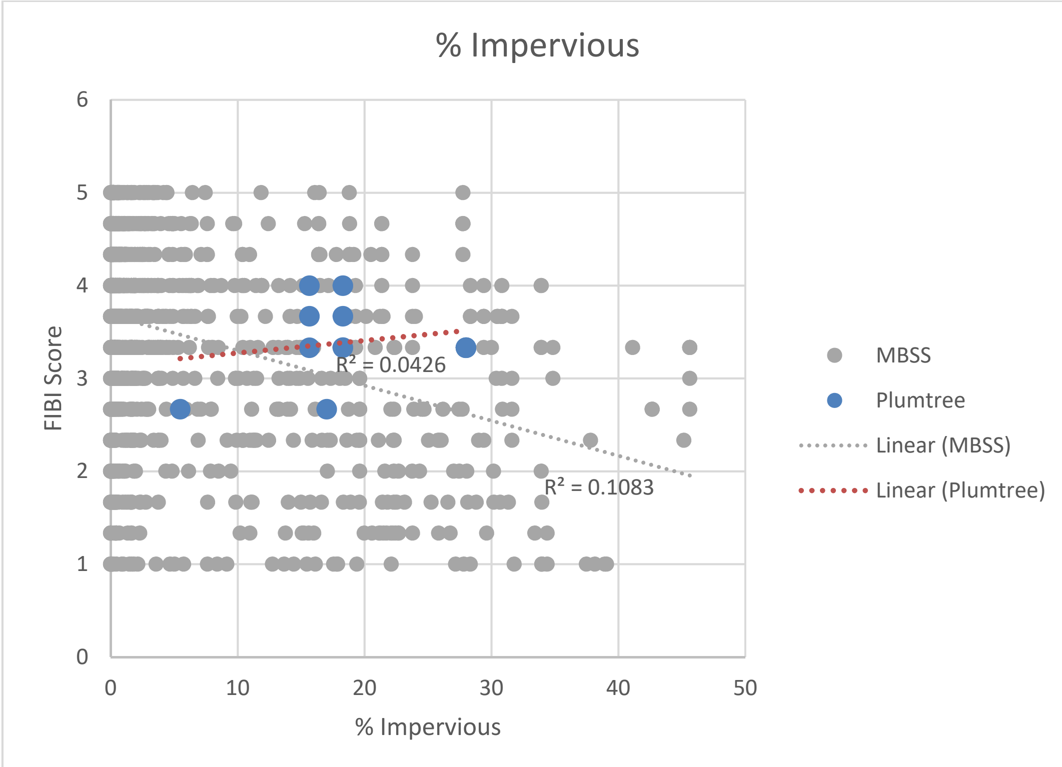

Figure 9 - FIBI score vs percent impervious land cover at Plumtree Run and MBSS (1995-2017) sampling sites

4.2 Conclusion

The Plumtree Run watershed is heavily urbanized like much of central Maryland. The ecological condition of the sites in Plumtree Run show impaired benthic macroinvertebrate communities with degraded physical habitat and high conductivity values. The fish communities at the Plumtree Run sites rates generally higher than the benthic macroinvertbrate communities. The high amount of urban land use and imperviousness likely result in higher, flashier storm flows that impact habitat quantity and quality, and result in high conductivity values from de-icing materials which cause lethal and sub-lethal effects on the freshwater organisms in Plumtree Run. Over the three years of monitoring the mean IBI scores have not changed significantly and there are no observable trends in condition over this time, which is not surprising as no restoration projects were implemented in the Plumtree Run watershed during these three years of monitoring. Harford County has plans to continue this monitoring in the future. Additional years of sampling will increase the number of samples and allow more sophisticated statistical analyses to detect changes in condition over time and as additional restoration projects are implemented.

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